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MULTIPLE WATER REUSE IN POULTRY PROCESSING:

CASE STUDY IN EGYPT

by

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16. ABSTRACT

An industrial-scale multiple water reuse system was under investigation for a period of four years at a modern poultry processing plant in Alexandria, Egypt.

The system involved: chlorination of cooling water from the compressor; reuse of this water in the chiller; successive transfer of an equivalent amount of water from the chiller to the prechiller, from the prechiller to the wash tank, and finally, from the wash tank to the scalder. Process waters in the prechiller and wash tank were alternately purified by diatomaceous earth filtration.

Long-term studies at the plant indicated successful utilization of a multiple reuse system with chlorinated water (20 mg/L input) and a water makeup rate of 20 m^3/day. Build-up of contaminants (total aerobic and coliform counts) and pollutants (Grease, suspended residue, BOD and COD) in the immersion tanks were compared to normal operation.

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

The poultry industry faces a unique situation in Egypt since new production farms and processing plants are located in remote areas as a part of an integral plan to revive the Egyptian deserts.

The stringency of water supply for the new plants, coupled with the compelling need for prodigious quantities of water, have led to the recognition of used water as a vital part of the water cycle in poultry processing. The study focused on application of multiple water reuse in poultry processing and its impact on sanitation of the process and product.

The conclusions and recommendations of this report are not directly applicable to poultry processing plants in the United States since water use in these plants is regulated by the U.S. Department of Agriculture.

For further information regarding this report, contact the Food and Wood Products Branch, Industrial Environmental Research Laboratory-Cincinnati, Ohio 45268.

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ABSTRACT

An industrial-scale multiple water reuse system was under investigation for a period of four years at a modern poultry processing plant in Alexandria, Egypt.

The system involved: chlorination of cooling water from the compressor; reuse of this water in the chiller; successive transfer of an equivalent amount of water from the chiller to the prechiller, from the prechiller to the wash tank and, finally, from the wash tank to the scalder. Process waters in the prechiller and wash tank were alternately purified by diatomaceous earth filtration.

Statistical analysis of data showed significant effects of water use rates,chlorine dosages and process times on the chemical and bacterial quality of the processed carcasses and water used in the immersion tanks. Response surface contours were developed for optimum operating conditions as tested in this plant.

Long-term studies at the plant indicated successful utilization of a multiple reuse system with chlorinated water (20 mg/l input) and a water makeup rate of 20 m^3/day. Build-up of contaminants (total aerobic and coliform counts) and pollutants (Grease, suspended residue, BOD and COD) in the immersion tanks were compared to normal operation.

Water renovation in conjunction with chlorination in the multiple water reuse system reduced water consumption to 54% of the normal rate and resulted in bacterial quality of carcasses superior to those processed in the normal system (where larger quantities of nonchlorinated potable water were used). Filtration of wash water resulted in better water and carcass quality than filtration of prechiller water.

Chlorination proved to be effective in reducing the rate of bacterial growth of the processed carcasses during cold storage at 4°c, however, chlorination may accelerate the rate of free fatty acid release during cold storage of carcasses. Moderate removals of pesticides from process water was achieved by adsorption on the filter cake during filtration.

This study demonstrated the potential for substantial reduction in potable water requirements during poultry processing by multiple reuse of processing water. Conserving potable water is an important economic factor in arid areas of Egypt.

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ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

APP	Alexandria Poultry Processing Plant.
MRS	Multiple Reuse System.
OPCONs	Operating Conditions (Water Makeup and Chlorine Dose).
TRTs	Treatment Schemes of the Multiple Reuse System.
COD	Chemical Oxygen Demand.
BOD	Biochemical Oxygen Demand exerted in 5 days.
TR	Total Residue.
TSR	Total Suspended Residue.
TVR	Total Volatile Residue.
TDR	Total Dissolved Residue.
O&G	Oil and Grease.
Kg/KKg LWK	Kg/100 Kg Live Weight Killed.
LOG TW = $\log_{10}$	Total Aerobic Count in Water/ml
LOG CW = $\log_{10}$	Coliform Count in Water/ml
LOG TC = $\log_{10}$	Total Aerobic Count per carcass
LOG CC = $\log_{10}$	Coliform Count per carcass

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This investigation was carried out by the Industrial Waste Research Center, High Institute of Public Health, Alexandria University. The principal investigator and author of this report was Dr. Ahmed Hamza. Dr.Samia Saad, co-principal investigator, was responsible for the analytical and laboratory research aspects of the project. Bacteriological analyses were conducted by Dr. Ebtisam El-Gazzwi and Ali Mourad of Alexandria University.

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SECTION I

INTRODUCTION

The alarming rate of population increase in Egypt, coupled with rapid expansion and diversification of industries without accompanying efficient pollution control schemes, has led to serious deterioration of the environmental quality. The growing awareness of the need to protect the environment has created a strong demand to abate pollution and conserve water in Egyptian industries.

In addition, the poultry industry is facing another unique problem. All new production farms and processing plants are being located in remote areas with limited sources of potable water.

The limited water supplies for new poultry processing plants, and the need for large quantities of processing water have forced the industry to recognize water recycling as a vital part of the water use system.

The cost for water and discharge represents a major part of total operating costs in many countries but not in parts of Egypt where water is still plentiful. However, in arid parts of the country or where suitable water sources are not available, the volume of water used and its cost become crucial.

Therefore, it is important to develop water use systems which lead to efficient conservation of both water and cost, and which require minimal technical expertise. The poultry industry is a suitable industry in which to achieve these aims by controlling processing procedures.

One approach to water conservation problems is the "multiple reuse concept". Multiple reuse of processing water conserves water, reduces cost of water treatment due to lower volumes discharged, and therefore, reduces capital and operating costs for wastewater treatment facilities;also, smaller amounts of potable water are purchased.

Water conservation in poultry processing can be accomplished either by reducing water requirements for given processing operations or by reuse of renovated processing water. Process modification was investigated in an EPA-funded study[1] at the Gold-Kist plant in North Carolina. Over a period of 27 months, several modifications resulted in a 32% reduction of water usage and 66% reduction in the waste load. These reductions resulted in a 53% decrease in municipal water and wastewater charges.

A survey[2] of 88 broiler processing plants in the US showed the average water use was 9.3 gallons/bird, the minimum figure of 4.2 gallons/bird applied to one plant which transported viscera by a vacuum system.

In the past, process modifications attracted more attention than water reuse because regulatory agencies either prohibited or discouraged application of water reuse systems. Recently, however, there has been an increased interest in water conservation through reuse or reduction in potable water requirements for given processes. Lillard [3,4 and 5] evaluated the feasibility of reusing processing water. She concluded that there was not necessarily a direct relationship between quality of processing water and quality of the product at certain points in processing. Further work in a 1/4 scale simulated giblet flume showed that necks flumed with untreated bird chiller water were equal in microbiological quality to necks flumed with potable water with regard to Salmonella incidence and levels, fecal coliform levels, and shelf-life, but total aerobic counts were 1/4 log higher for necks flumed with untreated chiller water. To eliminate this difference, bird chiller water was filtered through diatomaceous earth in a pressure leaf filter. She found that necks flumed with filtered, chlorinated chiller water were microbiologically equal in all respects to necks flumed with potable water. She also found that fluming giblets with filtered, chlorinated chiller water would reduce the demand on poultry processors for potable water and energy, and would also reduce the amount of water and organic matter discharged into municipal waste treatment systems.

Carawan[6] evaluated the replacement of potable water in selected parts of the gizzard splitting and peeling machine with a combination of chiller overflow and final bird wash water. He concluded that the use of chiller and wash waters for flushing of poultry gizzards has no detrimental effect on either the wholesomeness of the gizzards or that of the whole bird. The proper design of a system for reusing these waters could result in considerable water savings.

Recycling of chiller effluent was investigated by Rogers[7]. He concluded that the recycling system must be provided with the capability of removing solids and controlling the microbial population. Pilot scale results showed that diatomaceous earth filtration was the most feasible option and that it maintained bacterial levels of filtered chiller water below those of nonrecycled chiller water.

Wesley[8] reported that reducing fresh water input into chillers by half of current USDA requirements (0.5 gallon bird) resulted in carcass quality as good as the 75% or 100% metered chiller input volumes.

Clise[9] summarized the findings of Environmental Protection Agency (EPA) funded study to determine the feasibility of reclaiming poultry processing wastewater (total effluent) for reuse where potable grade water is presently required. Water which met the becteriological, chemical and physical Drinking Water Standards set by the Public Health Service was produced at a cost of $27/1000 gal. In June 1974, a second EPA project was funded which greatly broadened the evaluation of the safety of using renovated water. This project involved mixing the renovated water with well water on a 50/50 basis. This mixture was to be the water source for the processing plant. An equipment reconditioning and optimization phase, and a pilot testing phase were completed by June 1976. A report on these phases of the project by Andelman and Clise[10] concluded with the statement:

"In view of the urgent need to conserve our water resources, limit waste discharges, and improve water quality the nation will have to proceed to selective reuse of wastewater. Such a project as this is a useful step in that direction".

In early 1975 the General Poultry Company, the largest poultry processor in Egypt, requested the cooperation of the University of Alexandria in studing technological aspects and public health effects of various water renovation and reuse systems through inplant studies of the poultry processing operation.

With substantial technical and financial support from EPA, a four-year joint project was initiated in April 1976 by the High Institute of Public Health to develop, install and evaluate the feasibility of operating a multiple water reuse system at the Alexandria Poultry Processing Plant (APPP), one of the plants owned by the General Poultry Company.

SECTION II

CONCLUSIONS

Analysis of the research data acquired during the course of this study resulted in the following conclusions:

1- Multiple water reuse in immersion operations is a feasible approach to water conservation in poultry processing plants when reused water is filtered and chlorinated. Reduction of water consumption to 54% of the normal rate in the immersion tanks was achieved through renovation and reuse.

2- Chlorination and filtration of the reused water were effective in reducing levels of pollutants (COD, BOD, TR, TSR and O&G) and contaminants (total aerobic and coliform counts) in the immersion tanks.

3- The optimum operation of the multiple water reuse system in this plant was accomplished by the use of a water makeup rate of $20 m^3$/day accompanied by chlorine input of 20 mg/l. Cooling water from compressors can be used in lieu of potable water in the immersion tanks. Filtration of wash water in a closed loop was essential to maintain or improve the quality of carcasses processed with chlorinated reused water.

4- There were no significant differences between concentrations of the detected pesticides in the chlorinated and nonchlorinated potable water used at the plant. Moderate removals of pesticides through adsorption on filter cake was achieved in the filtering of process water.

5- Multiple water reuse with filtration and chlorination maintained the bacterial quality of processed carcasses and prolonged their shelf-life beyond shelf-life of carcasses processed under normal operating conditions in nonchlorinated water. However, chlorination accelerated the rate of free fatty acid release during cold storage of carcasses.

6- Pollution by trace metals during poultry processing did not occur, as concentration of trace metals in various

process effluents was similar to that of potable input water.

7-Manual handling during weighing and packaging resulted in noticeable recontamination of the processed carcasses. Elimination of human contact in this operation is required to upgrade the quality of the product.

SECTION III

RECOMMENDATIONS

Based on the results and conclusions drawn from this study, the following recommendations are proposed:

1- The poultry processing industry is encouraged to investigate effective multiple water reuse systems and to develop plant and process modifications which result in conserving water and reducing pollution loads. Specific areas needing attention are:

   a- Multiple recycling of the existing once-through water in the carcass cooling operation in most plants.

   b- Water flow to process units should be metered and recorded to permit better monitoring of water usage.

   c- Current potable water use in some plants for feather and viscera fluming, flushing of blood tunnels, and cleaning of coops and receiving areas should be re-examined. Water may be conserved by reusing water from other processes for these operations.

2- The success of a water conservation plan depends on the attitude of management and regulatory agencies. A well planned conservation program requires the full understanding and cooperation of all parties concerned. Coordination of activities between industry, regulatory agencies and research teams is necessary for development of efficient water conservation schemes.

3- Further research directed toward water conservation in poultry processing is recommended. Areas which require further investigation are:

   a- A long-term study to evaluate an integrated system of multiple water reuse in immersion processes, recycling cooling water, reuse of nonpotable process water for fluming operations and cleaning of receiving areas. The cost, potential accumulation of pollutants and contaminants, and the possible development of operational problems through extended use of multiple water reuse systems should be assessed

b- The marketing of recovered blood and oil could offset the cost of water conservation and waste abatement. The development of further uses for by-products would be useful in countries where these by-products are under-utilized.

c- Development of specific sensing devices for continuous monitoring of pollutants in water reuse systems would expedite regulatory approvals of water reuse systems.

SECTION IV

ALEXANDRIA POULTRY PROCESSING PLANT

DESCRIPTION OF THE PROCESSING OPERATIONS

Plant facilities were constructed in 1974-1975 and regular operation started in early 1976. The present plant capacity is 2500 birds/hr and actual processing time varies from 6 to 9 hours daily. Production at the APPP has been restricted by the availability of the broilers from the growing farms in the region.

Figure 1 is a schematic of the processing operations at the APPP. Following is a description of the major activities at the plant:

(a) Receiving and Killing

Poultry, usually broilers are transported from the farms by truck for processing on the day of arrival. The live birds are attached by their feet to shackles suspended from an overhead conveyor line which moves the birds to the killing station, where they are stunned by low voltage, and then slaughered by manual cutting of the throat blood vessels.

Water is used in this area for wetting the feathers and removal of blood, loose feathers and manure. A sizeable waste load is associated with the effluent from this area due to direct discharge of blood into the sewer system. Saving the blood for rendering is common in the US but not practiced on a large scale in Egypt.

(b) Scalding and de-feathering

Birds are subscaled at 54-60°C while adjusting the daily overflow to approximately 5 liter/bird (L/bird). The scalder effluent is highly contaminated with bacteria, blood and other residues. The scalded birds are de-feathered in three consecutive picking machines. The feathers are flumed to the rendering area, using fresh water and the scalder overflow. Feather fluming is the greatest water consuming process in the plant.

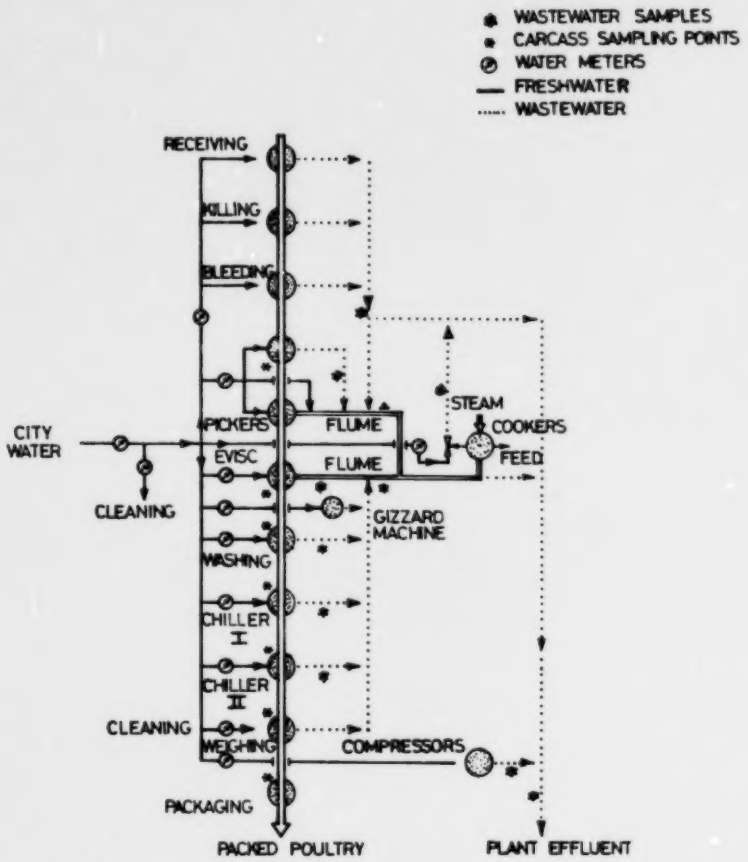


FIGURE 1. FLOWSHEET FOR ALEXANDRIA POULTRY PROCESSING PLANT

(c) Evisceration

Evisceration follows de-feathering without the intermediate process of whole bird washing. The first step in evisceration is feet cutting. The birds are rehung on an overhead conveyor which moves over the evisceration trough. Evisceration consists of opening the body cavity, removing the viscera and lungs and cutting the necks. Wastes from the evisceration process consist of inedible viscera, crops, heads, flesh, trimmings, grit and sand from gizzard cleaning. These wastes are termed "offal" and are flumed by water from the hand washing faucets located along the evisceration trough.

Giblets are cleaned and wrapped for bulk selling. After opening and washing the gizzards, they are transferred manually to the wrapping area without fluming, in order to save water.

(d) Washing and Chilling

The eviscerated carcasses are washed with fresh water in a horizontal immersion tank. The daily wash water usage averages 2 L/bird. Chilling is accomplished in two consecutive tanks at a combined daily overflow rate of 2L/bird which is equivalent to the requirements of US Department of Agriculture. The typical water temperature in the prechiller and final chiller are 15 and 9°C, respectively. The total residence time in both chillers is about 35 minutes. Effluents from both operations are discharged to the offal flume.

(e) Feather and Offal Recovery

The screened feathers and offal are cooked by direct contact steam to produce poultry feed. Waste steam is withdrawn from the cooker by jet ejector and condensed before discharge to the sewer system. The steam condenser is operated using once-through water system.

(f) Other Water Uses

Six ammonia compressors are used in the plant for production of ice for the chillers and for refrigeration and freezing of the processed carcasses. Fresh water is used in a once-through system for cooling the compressors. Water is also used for the cleanup operations in the packing and evisceration areas.

The water consumption for the individual production processes is shown in Table 1

Table 1. AVERAGE WATER USAGE FOR OPERATIONS AT APPP

Sample Station	Mean[1] (m^3/d)	Std.Dev. (m^3/d)	Process Water %	Total Water %
Killing & Bleeding	9.7	6.6	3.9	2.4
Scalding & defeathering	116.7	19.7	47.0	28.3
Evisceration	31.7	9.1	17.8	7.7
Giblet processing	10.6	4.3	4.3	2.5
Washing tank	27.7	10.5	11.2	6.7
Prechiller	16.5	7.2	6.6	4.0
Chiller	9.5	2.9	3.8	2.3
Cleaning (Packing area)	11.5	3.2	4.6	2.8
Cleaning (Eviscer.	14.6	4.3	5.8	3.5
Condenser effluent	95.5	28.5		23.2
Compressor cooling	50.7	10.6		12.3
Process water	248.2	27.7	100.0	60.2
Domestic uses	17.9	12.4		4.3
Total water	412.3	54.9		100.0

Notes:

1. Number of observations 69
2. Carcasses processed/d 13083
3. Process Water (L/bird) 19.0
4. Total Water (L/bird) 31.5

CHARACTERISTICS OF POULTRY AND PROCESS WATER (Normal operating conditions)

The waste loads of the individual processing operations presented in Table 2 were calculated from average flow concentration of pollutants and daily records of poultry Live Weight Killed (LWK). From each waste water sample point (see Figure 2) six sets of composite samples were collected during July 1976 and 12 sets of grab samples were collected between April and August 1976. As shown in Table 3, the average values for the grab samples were generally higher than the corresponding values of the composite samples.

The results indicate that the compressor cooling water is virtually clean, except for trace contamination by ammonia leaked from the compression cylinders (Table 3). This water is suitable for reuse as process water without significant health effects. As shown in Table 3, the chemical oxygen demand (COD) for many effluents is correlated to the 5-day biochemical oxygen demand (BOD). The dissolved oxygen (DO) values are depressed by oxygen demanding pollutants and increased temperature of the scalder effluent.

Discharge of the washing and chilling effluents to the offal flume results in noticeable dilution of the concentrated effluent from the evisceration process. Dilution of concentrated waste is undesirable as it increases both capital and operating costs of the effluent treatment facilities.

The concentrations of TR(Total Residue), COD and BOD successively decreased in the process water used in the washer, prechiller and chiller. This suggests the possibility of counter-current reuse of water from the chiller to the prechiller and then to the washer. The reuse of chiller water in the prechiller is an approved practice in the United State.

Trace metal concentrations in various effluents are shown in Table 4. The relatively high iron concentration in the killing, scalding and eviscerating effluents may be due to blood contamination or possibly, due to corrosion of fittings and pipelines at elevated scalding temperatures. Trace metal concentrations in the compressor cooling water are almost identical to those in the fresh water.

Furthermore, concentration of trace metals in various effluents is within the standards for fresh water, which indicates near absence of trace metals pollution during poultry processing. Magnesium and iron concentrations in some processes exceed the desired levels for drinking water in the U.S. However, neither element constitutes a health hazard in processing water.

Table 2 AVERAGE WASTE LOAD FOR OPERATIONS AT APPP

Sampling Station	COD Kg/d[1]	COD Kg/KKg[2] LWK	BOD Kg/d	BOD Kg/KKg LWK	TR Kg/d	TR Kg/KKg LWK
Bleeding effluent	30.8	2.1	22.8	1.6	41.7	2.9
Feather flume	217.5	15.1	165.7	11.5	225.6	15.7
Evisc. & giblet process	60.9	4.2	39.4	2.7	70.9	4.9
Washing effluent	39.7	2.8	33.4	2.3	48.3	3.4
Prechiller effluent	30.9	2.1	23.6	1.6	35.0	2.5
Chiller effluent	12.9	0.9	9.7	0.7	14.8	1.0
Condenser effluent	132.5	9.2	108.9	7.6	163.5	11.4
Final effluent	530.0	36.8	426.8	29.6	609.6	42.3

1 Kg/d= Kilogram/day
2 Kg/KKg LWK = Kg/1000 Kg Live Weight Killed
[slaughtered birds averaged 14.4 KKg LWK/ day]

Table 3. ANALYSES OF WASTEWATER FROM EFFLUENTS OF APPP
(mg/1)

A. Grab Samples

		Temp°C	pH	D.O	NH_3-N	SO_4	COD	BOD	TR	TVR	O&G
Final Effl.	$\bar{x}$	31.0 C	6.8	0.2	29	50	1581	1306	1974	1368	102
	S.D	1.5	0.4	0.5	14	7	365	323	331	327	67
	R							0.7	0.5	0.1	
Bleeding Effl.	$\bar{x}$	26.2	6.7	0.0	45	63	3265	2341	4288	3163	88
	S.D.	1.6	0.3	0.0	19	14	1571	858	1882	1640	51
	R							0.8	0.7	0.8	
Scalder Effl.	$\bar{x}$	58.0	7.0	0.0	28	49	1330	878	1556	1121	68
	S.D.	1.7	0.2	0.0	22	8	597	573	338	462	42
	R							0.9	0.9	0.9	
Feather Flum	$\bar{x}$	40.5	7.0	0.5	28	52	1449	937	1687	1069	111
	S.D	4.8	0.3	1.3	16	9	707	472	611	420	63
	R							0.8	0.8	0.6	
Eviscer Effl.	$\bar{x}$	26.2	6.4	0.4	29	53	2195	1678	2369	1806	316
	S.D	1.5	0.4	0.6	12	14	748	509	854	800	202
	R										
Offal Flume	$\bar{x}$	25.5	6.9	2.0	28	48	1582	1156	1784	1218	208
	S.D	1.1	0.4	1.7	17	6	802	525	820	828	101
	R							0.9	0.9	0.9	
Washing Effl.	$\bar{x}$	26.5	7.1	4.4	28	51	1303	1061	1485	981	229
	S.D	2.6	0.3	2.3	21	7	358	422	385	373	124
	R							0.9	0.9	0.9	
Prechill. Effl.	$\bar{x}$	14.8	71.	2.9	28	47	1193	956	1411	985	270
	S.D	3.1	0.3	1.7	20	9	471	475	509	497	219
	R							0.9	0.9	0.9	
Chiller Effl.	$\bar{x}$	8.6	7.4	4.3	29	45	884	758	1093	644	239
	S.D		0.6	1.5	20	8	477	744	454	346	82
	R							0.3	0.9	0.7	
Condenser Effl.	$\bar{x}$	55.9	7.4	2.0	24	49	1123	942	1297	960	182
	S.D	1.2	0.3	2.4	17	11	197	236	291	307	131
	R							0.9	0.7	0.8	
Compressor Effl.	$\bar{x}$	28.7	7.7	6.4	36	39	30	9	378	123	5
	S.D	0.6	0.5	1.0	48	6	13	6	273	77	5
Fresh Water				7.1	6	46	21	5	360	94	

Continued

Table 3 (continued)

B- Composite Samples

		pH	D.O	SO_4	COD	BOD	T R	TVR	O&G
Final Eff.	$\bar{x}$	7.1	0.38	51	1286	1035	1479	1082	269
	SD	0.2	0.19	11	235	124	204	70	172
	R					0.8	0.9	0.6	
Scalder	$\bar{x}$	7.0	0.13	59	1574	1235	1701	1208	91
	SD	0.2	0.15	16	158	118	192	187	34
	R					0.5	0.9	0	
Combined Feather &Offal Fl.	$\bar{x}$	7.2	0.23	43	1788	1498	1887	1282	41
	SD	0.2	0.57	3.7	47	60	57	88	22
	R					0.3	0.9	0.7	
Washing Eff.	$\bar{x}$	7.3	4.2	60	1434	1220	1744	1319	262
	SD	0.2	1.1	1.3	29	40	273	370	14
	R					0.7	0.1	0.3	
Rpechiller	$\bar{x}$	7.2	1.30	43	188	1431	2119	1328	244
	SD	0.2	1.12	3	260	246	305	100	85
	R					0.7	0.9	0.6	
Chiller	$\bar{x}$	7.2	1.55	57	1357	1020	1562	1082	245
	SD	0.2	0.69	4.8	110	283	242	211	104
	R					0.9	0.7	0.9	
Condenser Effl.	$\bar{x}$	7.5	0.55	44	1388	1141	1712	1213	33
	SD.	0.4	0.45	15.8	262	198	403	298	16
	R					1.0	0.9	1.0	

A $\bar{X}$ = Mean
S.D. = Standard deviation
R = Correlation between COD and BOD;TR and TVR
No. of observation of grab samples = 12
No. of observation of composite samples = 6

Table 4. TRACE METALS IN GRAB SMPLES OF WASTEWATER FROM APPP (ug/1)

Sample		Co	Cr	Zn	Ni	Pb	Mn	Cu	Fe	Cd
Final	R	2-16	2-17	34-117	1-6	1-12	19-180	23-60	130-800	2-3
	$\bar{x}$	5.8	5.6	61.8	3.0	3.6	72.3b	36.1	485b	2.1
	SD	4.7	5.1	36.0	1.9	3.7	51.7	11.3	220	0.4
Bleed.	R	1-18	1-13	25-200	1-4	1-12	21-210	20-40	180-360	1-4
	$\bar{x}$	7.0	4.9	68.9	2.6	2.8	61.4b	27.1	470b	3.0
	SD	5.7	4.0	60.5	1.1	4.1	66.2	7.2	165	1.1
Scald.	R	1-18	1-12	21-170	1-5	1-14	26-210	21-40	201-810	1-6
	$\bar{x}$	7.1	6.0	57.4	2.6	3.5	62.50	29.4	524b	2.7
	SD	5.3	4.6	48.1	1.4	4.6	62.9	7.8	222	1.6
Feather	R	2-15	0-12	22-190	2-5	1-12	13-180	15-40	215-640	1-4
	$\bar{x}$	7.4	5.4	64.3	3.4	3.0	53.3b	28.3	427b	2.9
	SD	4.2	4.9	54.3	1.2	3.7	55.0	7.6	132	0.1
Evisc.	R	1-17	1-8	31-150	1-4	1-14	14-130	20-40	210-130	1-5
	$\bar{x}$	7.8	4.4	64.5	3.1	2.9	53.5b	30.6	466b	2.7
	SD	5.9	3.1	37.9	1.3	4.5	36.1	6.8	165	1.4
Offal	R	1-7	1-14	28-130	1-5	1-22	13-140	20-40	310-530	1-4
	$\bar{x}$	7.8	5.3	67.5	3.0	4.1	49.5	28.3	419b	2.3
	SD	5.8	4.9	34.4	1.5	7.3	40.8	8.1	68	1.0
Wash.	R	1-17	1-12	28-90	1-8	1-12	12-72	20-40	190-400	1-2
	$\bar{x}$	6.3	5.8	62.0	3.5	4.0	26.7	29.7	311b	1.8
	SD	6.3	4.0	25.8	2.6	4.6	22.5	6.4	95	0.5
Prechill.	R	2-19	1-8	21-110	1-9	1-10	10-160	20-180	90-500	1-3
	$\bar{x}$	8.3	3.8	66.4	3.6	3.3	44.0	51.9	279	2.4
	SD	5.2	2.8	27.4	2.7	3.9	52.2	53.7	142	0.8
Chiller	R	3-18	1-6	30-120	1-5	1-9	10-220	18-32	210-650	1-3
	$\bar{x}$	9.1	3.4	68.4	3.1	3.5	61.4b	27.1	374b	2.0
	SD	4.7	1.9	34.1	1.6	3.3	86.3	6.0	147	0.8
Cond. water	R	2-14	1-9	26-140	1-9	1-8	9-140	13-100	240-890	1-5
	$\bar{x}$	8.3	3.5	61.5	3.7	2.3	50.3b	38.7	454b	2.6
	SD	3.8	3.1	44.7	2.9	2.8	58.7	35.2	255	1.8
Comp. water	R	2-18	1-15	32-190	1-12	1-14	10-190	9-40	120-600	1-3
	$\bar{x}$	7.9	4.9	70.1	3.1	2.8	63.5b	25.4	362b	2.0
	SD	4.7	4.4	53.1	3.7	4.6	66.3	12.8	155	0.2
Fresh water	$\bar{x}$	8.2	5.1	62.3	2.8	3.1	61.1	23.2	293	2.2
Water stand.		-	50	-	-	50	50	1000	300	10

R= Range, X = Mean, SD. = Standard Deviation, n = 8
b = Values exceèd PHS drinking water standards.

Bacterial identification, total aerobic and coliform counts of the various effluents are shown in Table 5. The highest coliform and total aerobic counts were found in effluent from the evisceration line.

Fewer organisms were recovered from water in the scalder and feather flume. This may be due to cell injury, a reduction in viable cells due to high scalding temperatures, or due to dilution by fresh water input.

The lower counts from water in the offal flume compared to effluent from the evisceration line are probably due to the diluting effect of the washing and chilling effluents.

The most prevalent bacteria in the effluents were E. coli (an indicator of fecal contamination), and Pseudomonas and Proteus (spoilage microorganisms). Salmonella, Para colon, Shigella and Staphylococci (bacteria of public health significance) were identified in several samples. Cooling water from the compressors was relatively free of bacterial contamination.

Table 6 shows the levels and types of bacteria recovered from carcass samples. Heavy contamination was observed after both scalding and evisceration. Washing decreased coliforms and total aerobic counts on the carcasses by 3-4 orders of magnitude and chilling decreased these counts on carcasses by two additional orders of magnitude.

Coliforms and total aerobic counts (indicators of general sanitary conditions) increased again during final weighing and packaging operations. This recontamination due to manual handling indicates the need to eliminate or minimize contact during these operations.

Effluent from the scalder, evisceration trough, washing and chilling tanks were either free of or contained antimicrobial residues below the sensitivity limit of 25 ug/l chloramphenicol.

Table 5. MICROOGRANISMS ISOLATED FROM WASTEWATER SAMPLES

Sampling Station	No. of Observations	Percent Positive Samples											Mean count/ml	
		Escherichia coli	Proteus	Preudomo-nonas	Salmonella typhi	Salmonella para typhi A	Salmonella para typhi B	Para colon	Shigella	Staphylococci	Streptococci	Micrococci	Total aerobic	Coliform
Final	19	76	10	57	5	5	5	23	5	19	5	5	9.9×10^{8}	4.3×10^{6}
Scalder	18	66	16	11	5	32	22	32	66	77		11	3.3×10^{7}	2.9×10^{5}
Defeather.	21	100	23	5		5	5	9.5	19				5.3×10^{7}	4.0×10^{5}
Eviscer.	21	95	33	33				5	9.5				6.4×10^{11}	7.4×10^{10}
Offal	21	95	39	19	9.5	5	9.5	19	5	14	5	19	1.9×10^{8}	2.7×10^{6}
Washer	20	85	33	28	5	19		28	14	9.5	14	28	1.0×10^{5}	2.0×10^{3}
Prechiller	21	85	33	57	9.5	9.5	5	9.5	9.5	5	14	14	4.9×10^{4}	2.1×10^{3}
Chiller	21	76	14	62	23	9.5		19	5	14	5	14	6.9×10^{4}	1.3×10^{3}
Condenser	14	64	28		14	14	7	7			7	7	1.2×10^{4}	1.5×10^{3}
Compressor	14	28		14	7								1.1×10^{2}	

Table 6. MICROORGANISMS ISOLATED FROM PROCESSED CARCASSES

Sampling Station	No. of Observations	Percent Positive Samples									Mean count/carcass	
		Escherichial coli	Proteus	Pseudomonoas	Salmonella typhi	Salmonella para typhi A	Salmonella para typhi B	Shigella	Streptococci	Micrococci	Total aerobic	Coliform
Scalder	18	72	16.6	11.1						5.6	1.8×10^{9}	1.7×10^{7}
Eviscer.	18	88.9	38.9	50.0	16.0	5.7	5.7	11.1		11.1	3.0×10^{12}	4.6×10^{10}
Washer	12	83.8	25	58.3	8.3						3.9×10^{12}	4.6×10^{10}
Prechiller	12	100	33.3	41.7	25.0	8.3	8.3	16.7	25.0		1.6×10^{6}	9.8×10^{4}
Chiller	18	88.9	44.4	38.9	27.8	11.1	33.3				1.9×10^{6}	5.6×10^{4}
Weighing	12	100	33.3	75.0		8.3			25.0	8.3	1.6×10^{7}	4.2×10^{5}
Packaging	18	77.8	27.8	66.7	22.2	11.1		16.6	55.6		4.6×10^{7}	3.1×10^{6}

SECTION V

MATERIALS AND METHODS

SAMPLING AND TESTING METHODS

Composite samples were collected by automatic samplers, and grab samples were collected according to a specific scheme described for each phase of the study;chemical analyses were performed in accordance with EPA methods for Chemical Analysis of Water and Wastes[11].

Samples for trace metal analyses were concentrated according to a method described by Price[12] and measured by atomic absorption spectrophotometry as described in Standard Methods for Examination of Water and Wastewater[13].

All necessary precautions were taken during transportation to ensure the integrity of the samples. This included addition of preservatives, cold storage and the use of various types of sample bottles and vials[11].

Dechlorination of samples for bacteriological analyses was achieved by addition of sodium thiosulfate[13].

Water samples (100 ml) were collected for bacteriological analyses in sterile glass containers and kept cold until analyzed. Carcasses were placed in specially prepared U.V. treated polyethylene bags, 0.2 L distilled water was added, followed by shaking for 5 minutes. After shaking, the rinse water was filtered through sterile No. 1 filter paper. Total aerobic and coliform counts were performed by plating Difco blood agar and MacConkey agar respectively according to methods described by Cruickshank[14]. Methods for bacterial identification are described by Hallman and Burkhard[15]. Testing for antimicrobial agents was performed by methods described by Huber et al[16].

The multiple water reuse system at the APPP is illustrated in Figure 2.

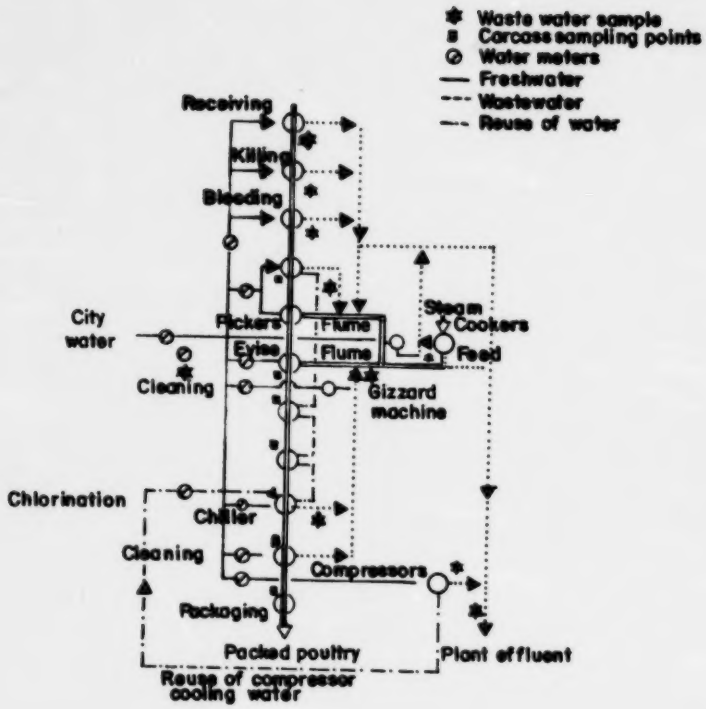


Figure 2 MULTIPLE WATER REUSE SYSTEM AT ALEXANDRIA POULTRY PROCESSING PLANT

DESCIPTION OF THE SEVEN EXPERIMENTAL PHASES OF THE WATER REUSE STUDIES

Phase I

A study of build-up of contaminants in the four immersion processes (Scalding, washing, prechilling and chilling) was undertaken to provide basic information on the quality of water and carcasses during normal processing.

The normal operation at the APPP involves initial filling of the immersion tanks (scalder 6.7m^3, washing tank 5m^3, prechiller 2.5 m^3, chiller 2.5 m^3) every morning and introducing continuous makeup with once- through fresh water in all tanks. Frequently, in the middle of the processing period, all tanks are emptied and refilled with fresh water. Refilling depends on the operators' judgment for the need to renew the processing water. During this study, tanks were not emptied and refilled. However, overflow from the tanks was kept constant for each process at the average rate for this plant, predetermined in an initial survey during 8 hours of normal operation. These rates were 55 m^3, 22.7m^3, and 21 m^3 for the scalder, washer, and chillers, respectively.

For chemical and microbiological analyses, water samples were taken from the tanks after one hour of operation and hourly after that for a total of 6 hours on four different sampling days (May 1976). This sampling procedure was repeated on seven different sampling days (November / December 1976) to evaluate the bacteriological quality of carcasses and water. One carcass and one water sample were taken hourly from each processing tank. Levels of total aerobic organisms and coliforms were determined.

Phase II

Reuse of non-renovated water was evaluated from April to September 1977. Processing water was continuously pumped at a controlled rate from the chiller to the prechiller and repumped at the same rate from the prechiller to the washing tank (counter-current flow); The overflow from the washing tank was diverted to the scalder as partial replacement of the fresh water requirement. Samples were taken hourly for a total of 6 hours during each of 12 sampling days. Sampling days were one week apart. Schematics of processing water flow for processing operations with and without water reuse are shown in Figure 3.

In this phase, five different rates of makeup water (20,25,30,35 and 40 m^3/day) were used in the multiple reuse system.

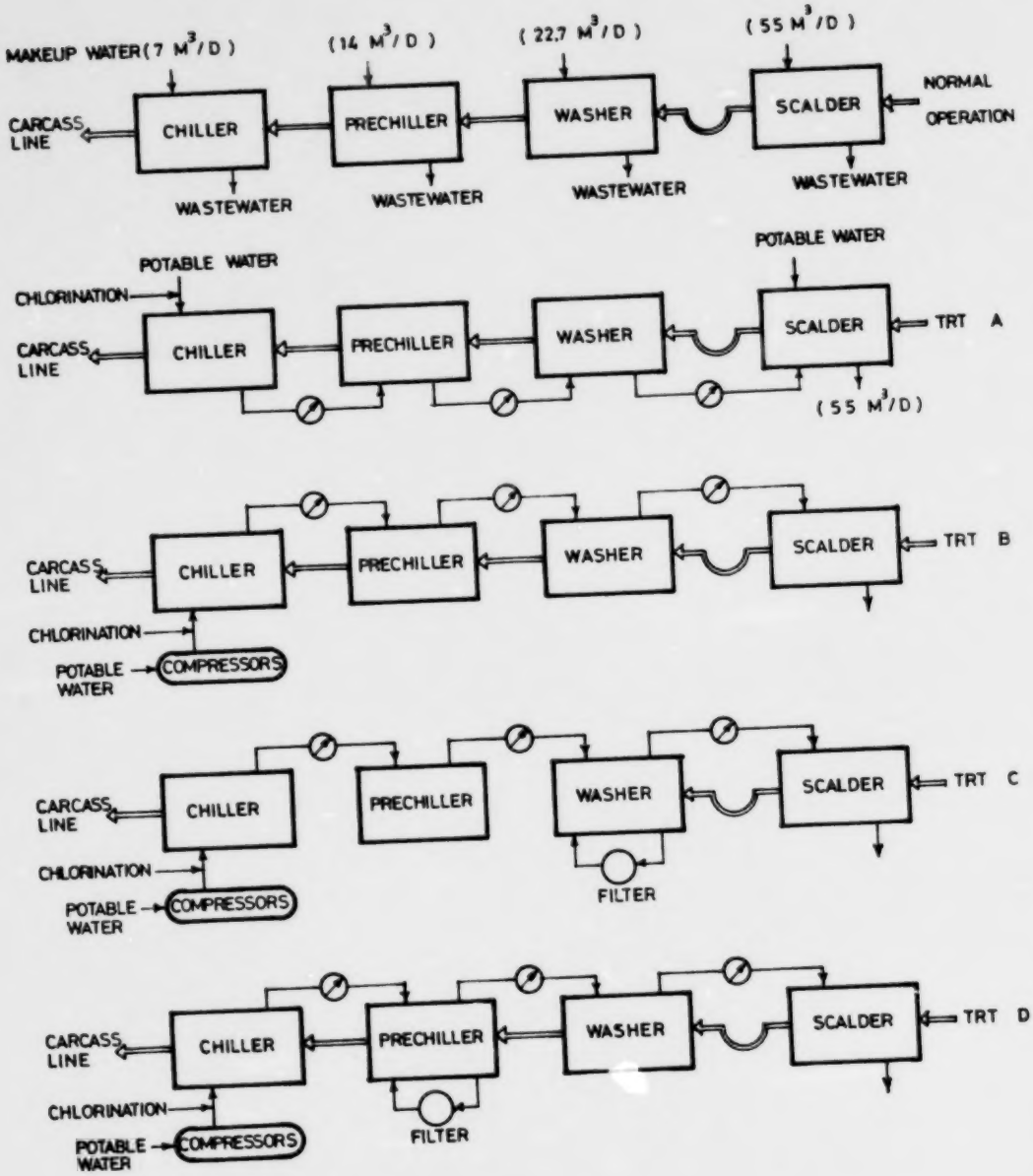


FIGURE 3. SCHEMATICS OF NORMAL OPERATION AND MULTIPLE REUSE SYSTEMS

Table 7 shows the ratios of makup water of reuse to non-reuse schemes for these five rates.

Table 7 RATIO OF MAKEUP WATER USED IN THE REUSE AND NON-REUSE STUDIES

Makeup m^3/d	No. of Expts	Chiller (2.5[1]+7.0[2])	Prechiller (2.5+14)	Washer (5.0+22.7)
20	3	2.86	1.43	0.88
25	3	3.57	1.78	1.10
30	2	4.28	2.14	1.32
35	2	5.00	2.50	1.54
40	4	5.71	2.85	1.76

1 Initial filling water m^3/d
2 Makeup water in normal system m^3/d

Because makeup requirements for the scalder were greater than the amount discharged from the washed potable water was also added to the scalder. Fortyfive to 82% of makeup water to the scalder consisted of potable water.

Phase III (Treatment A)

In this phase (designated Treatment A) the multiple reuse of water described in Phase II was repeated and accompanied by the chlorination of potable water entering the four immersion tanks (October 1977 - February 1978). An advance gas chlorinator (Capital Control Co., USA) was installed on the subfeeding line of the tanks. Metered chlorine dosages were injected into the line during initial filling (about one hour prior to start up). Chlorine dosages were controlled during the initial filling of tanks and in makeup waters. After start up, the presence of blood, grease and other contaminants in the processing waters made it difficult to control residual chlorine levels during the entire processing period. However, the concentration of residual chlorine in the four immersion tanks was monitored frequently and the results were averaged for each level of chlorine used. Total residual chlorine was measured by the titrimetric, DPD-FAS method[11].

Eleven tests were performed in which chlorine was metered into the water at three makeup rates of 10, 20 and 30 m^3/day.

Phase IV (Treatment B)

Following the construction of an underground concrete tank with net storage capacity of 20,000 liters,

a study was initiated to assess the effect of using the cooling water from the compressors as a substitute for fresh water input into the immersion tanks.

A totally closed system was installed for collecting and storing cooling water from the compressors to eliminate potential contamination of the stored water. A pumping system was installed to supply the cooling water to the immersion tanks. Experiments were carried out between March and July 1978, using the cooling water as makeup water for the immersion processes. This system was designated "Treatment B" in the statistical analysis of data. Chlorine dosages used were 10,20, 30 and 40 mg/l and water makeup rates were 10,20 and 30 m^3/day.

Phase V (Treatment C)

In September 1978 a high-pressure diatomaceous-earth, leaf filter (Model 36H-80S-4, Amafilter, Holland) was installed at the APPP. The filter has eleven leaves, a net filtering area of 7.5 m^2, tank volume of 1.1 m^3, and maximum working pressure of 4.5 Atm. During normal operation the filter produces an average of 1000 L/hr filtered water. Although a larger filter with more filter leaves and greater capacity would have been preferable, it was decided to use the above experimental type due to budgetary limitations. Preliminary investigation indicated that most local diatomaceous earths were not suitable for coating the leaves. These grains settled rather than coat the leaves due to the fine grain size. A special bentonite earth (Aswan clay - equivalent pore size 0.8 u) which coated the leaves satisfactorily was obtained from the Egyptian company for Refractories.

The filter was connected to the washing tank in a closed loop in order to recycle filtered wash water. Phase V was similar to phase IV with two exceptions:

a) The maximum chlorine dosage was limited to 30 mg/L.
b) Wash water was renovated by filtration and used in conjunction with the multiple water reuse system.

This phase was designated "Treatment C". Eight experimental runs were performed between October and December 1978. Chlorine dosages used were 10,20 and 30 mg/l, and water flow rates were:10, 20 and 30 m^3/day.

Phase VI (Treatment D)

In this phase the prechiller water was filtered rather than the washing water. All other experimental conditions were the same as described in Phase V.

This phase was designated "Treatment D".

This treatment was used in eight experimental runs between January and February 1979.

Chlorine dosages and water flow rates were the same as those used in Phase V.

Phase VII

The final experiments were performed between May and August 1979. In this period treatments C and D (Phase V and VI) were run without the use of chlorine to provide control data for two experiments.

Treatments C and D without Chlorine were repeated 4 times during the final experimental peroid.

STATISTICAL ANALYSIS

Statistical Analysis of experimental data were those described in SAS User's Guide[17]. Analysis of variance (ANOVA)was used with grouping variables TRTs (A,B,C, and D), operating conditions (water makeup rate and chlorine dosage) processing time and date (to account for seasonal variations) and the interactions of these variables.

A response surface model was used to evaluate the effect of the operation conditions (makeup rate and chlorine dose) on selected chemical and bacterial quality indicators. Since the operating conditions represent quantitatives variables, it is possible to compute the response "y" as a function of the levels of these variables according to the following model:

$$y_n = \lambda(x_{1n}, x_{2n}) + e_n$$

where

λ = the response surface

x_1 = level of makeup rate

x_2 = levels of chlorine dose

e_n = the experimental error of "n" observations

When the mathematical form of "λ" is not known, this function can be predicated within the range of the experimental variables by a ploynomial in the variables x_n.

However, these polynomials are not dependable when extrapolated beyond the range of experimental conditions. Response surfaces shown in the following chapters should be regarded only as an approximation to "λ" within the region covered by the experiment.

SECTION VI

RESULTS AND DISCUSSION

COMPARISON OF WATER AND CARCASS QUALITY FROM THE NORMAL OPERATION AND THE MULTIPLE WATER REUSE SYSTEM WITHOUT RENOVATION

Normal Operation (Phase I)

At the startup of operation, water quality was the same in both the normal and the water reuse systems because the immersion tanks in both instances were initially filled with potable water. However, as pollutants and contaminants accumulated in water, the effect of processing time on water and carcasses was considered.

The accumulation of pollutants and bacteria in the four immersion tanks and on carcasses under normal operating conditions is illustrated in Figures 4 and 5, respectively. Except for the DO, all monitored chemical and bacterial parameters increased with processing time. Figure 5 shows an improvement in bacterial quality of carcasses going through the various stages of operation from scalding to washing and chilling.

Even though potable water is required in all phases of processing to ensure a safe and wholesome product, potable quality of the water is lost as soon as carcasses are introduced into immersion tanks. The magnitude of water deterioration was highest in the scalder and lowest in the chiller. Introduction of potable makeup water is intended to dilute pollutants and thus ensure safety and quality of the processed carcasses. However, potable makeup water does not preserve the potable quality of water in immersion tanks once processing has started.

Multiple Reuse of Non-Renovated Water (Phase II)

The magnitude and rate of change of chemical pollutants due to water reuse at various makeup rates are illustrated in Figure 6. In most instances the increase in makeup rate between 20 and 40 m^3/d was associated with an improvement in quality of the immersion water. This was manifested by the

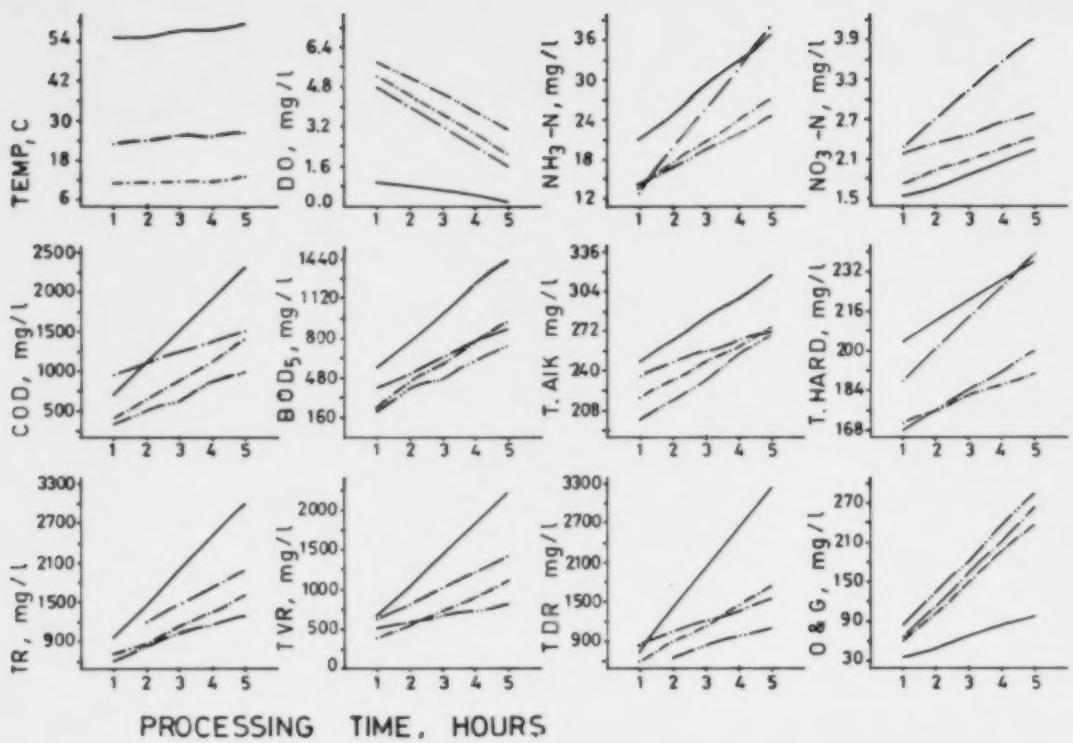


Figure 4. ACCUMULATION OF POLLUTANTS IN THE IMMERSION TANKS IN THE NORMAL SYSTEM [PHASE I]

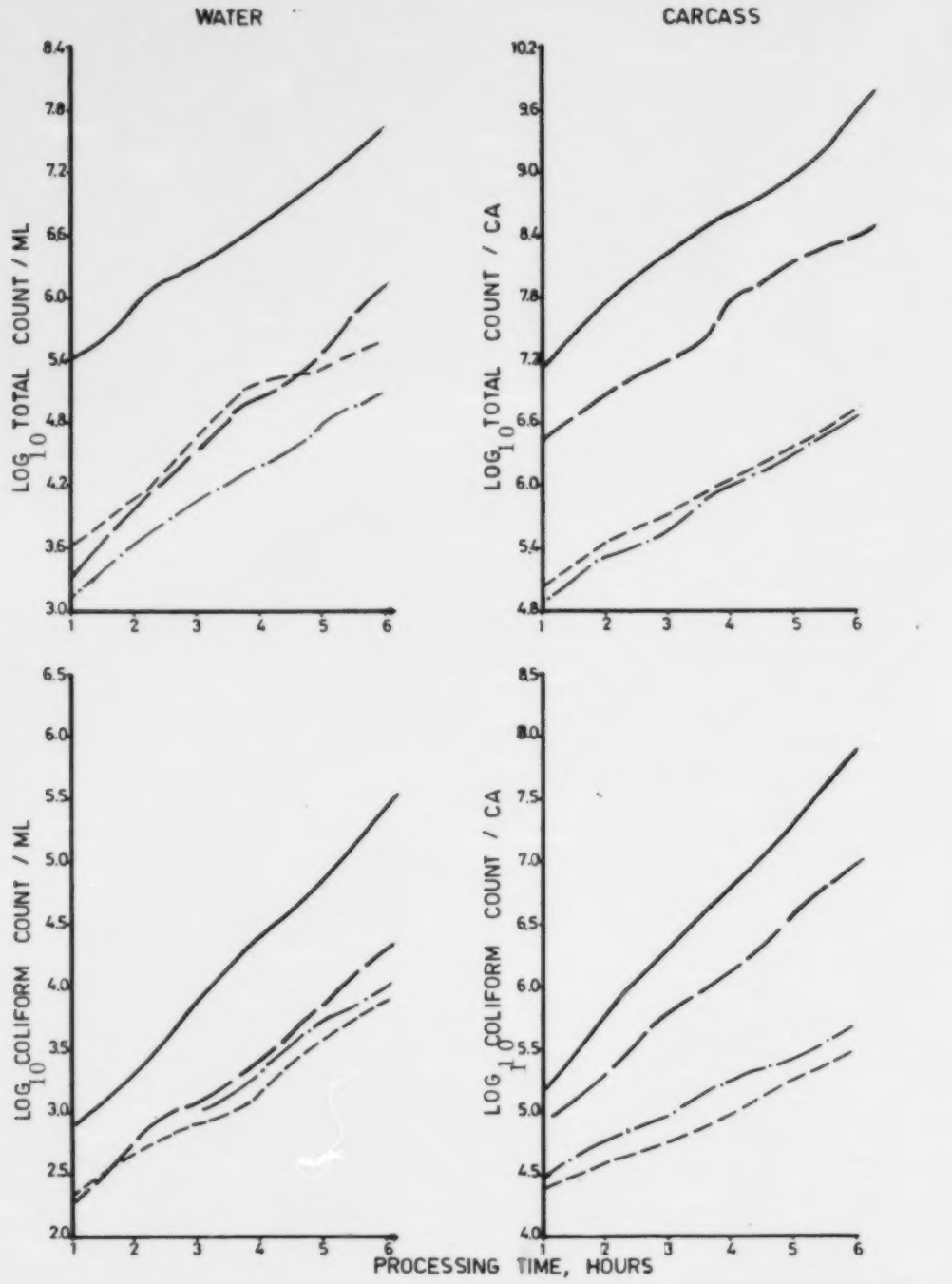


Figure 5. ACCUMULATION OF BACTERIA IN THE IMMERSION TANKS IN THE NORMAL SYSTEM [PHASE I]

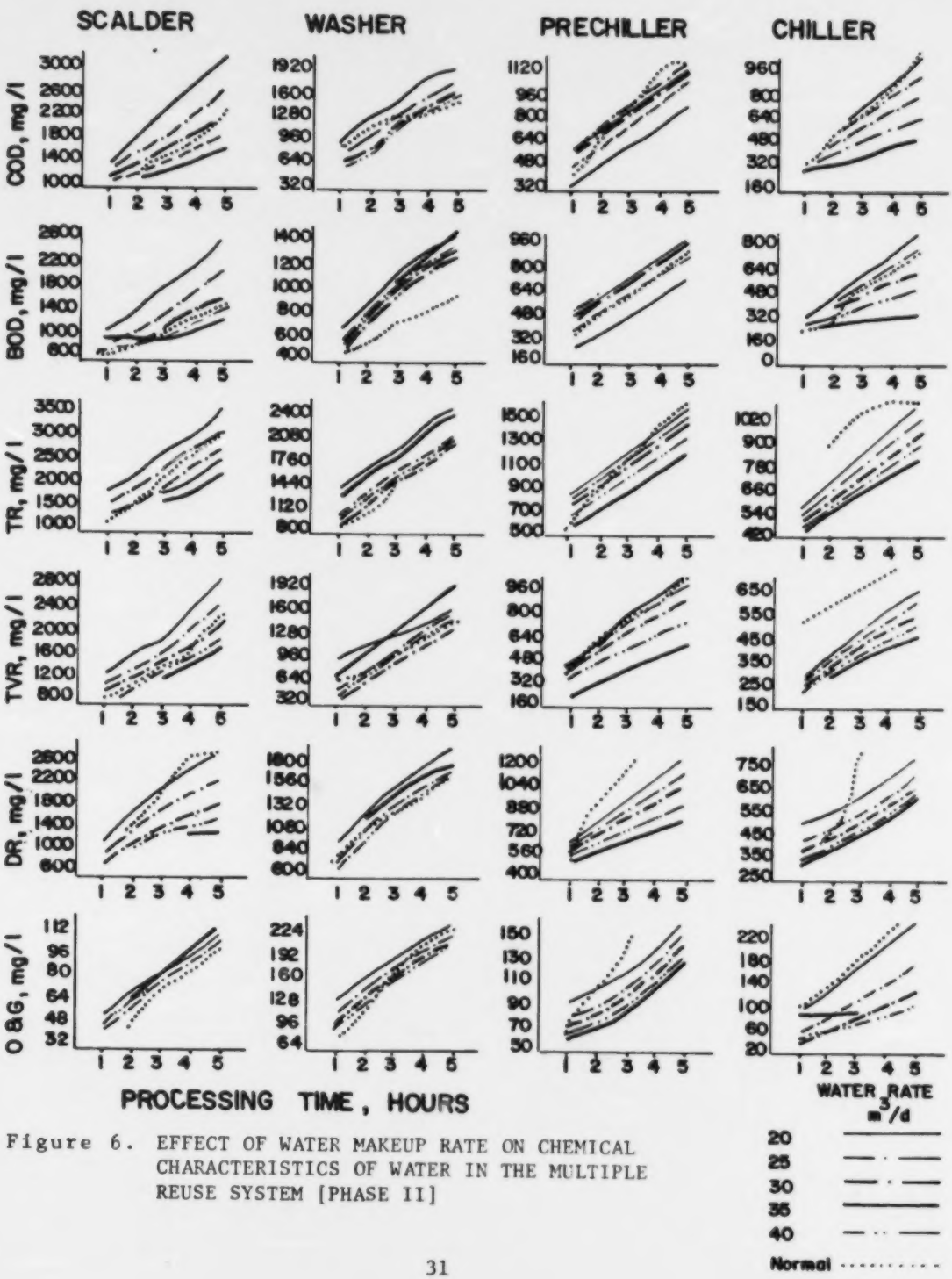


Figure 6. EFFECT OF WATER MAKEUP RATE ON CHEMICAL CHARACTERISTICS OF WATER IN THE MULTIPLE REUSE SYSTEM [PHASE II]

successive decreases in magnitude and rate of accumulation of chemical pollutants.

Table 8 summarizes the results of the ANOVA for the effects of water makeup rate and processing time on the tested pollutants. In most cases both variables showed significant effects on the concentration of chemical pollutants. However, the effect of makeup rate on the chemical quality of the wash water was not significant. As shown in Table 7 the use of water makeup rate of 30 m^3/d represents an increase of water use in the chiller to 4.28 times the normal system, while the same makeup rate in the washer represents only an increase of 1.32 times the amount used in the normal system. In general the quadratic effects (H^2,Q^2) and the interaction between water makeup rate and processing time (H * Q) were not significant.

Figure 7 illustrates the effect of time and various water makeup rates on the bacterial counts of processing water and carcasses. The ANOVA in Table 9 designates the counts at various makeup rates which were significantly different. In several instances the increase of water makeup rate from 20 to 40 m^3/d did not result in significant improvement of bacterial quality of processing water and carcasses (Table 9). Bacterial quality of carcasses and water deteriorated with time in all cases (Figure 7 and Table 9).

Comparison of the Normal and Multiple Reuse Systems (Phase I and II)

Criteria for considering multiple water reuse satisfactory in this study were based on equal or better carcass quality and equal or improved water quality compared to the normal once-through processing with potable water.

Microbiological criteria used were total aerobic and coliform counts. Criteria for chemical quality of water were COD, BOD, TR AND O&G. The effects of the normal once-through system (PhaseI) and non-renovated multiple reuse system (Phase II) on the quality of carcasses and water are shown in Table 10.

The results of Table 10 and plots illustrated in Figures 6 and 7, reveal the following facts:

1- In the scalder, with few exceptions, there was no significant difference between chemical and bacterioligical means of samples from normal operating conditions and the non-renovated multiple water reuse system for water and carcasses. This is probably due to the constant rate of water makeup to the scalder (55 m^3/d) in both systems. The significant increases of organic pollutants observed in a few instances in the multiple water reuse in the scalder were probably due to accumulation oc organics in the reused water from the preceding process (wash water).

2- In the washer, there was generally no significant difference in quality of carcasses or processing water from both water use systems (normal and multiple reuse). The notable exceptions were significant

TABLE 8. EFFECT OF WATER MAKEUP RATE AND OPERATING TIME ON CHEMICAL CHARACTERISTICS OF THE REUSED NON-RENOVATED WATER

PROCESS	PARAMETER	SOURCE				
		HOURS (H)	MAKEUP (Q)	H^2	Q^2	H*Q
SCALDER	COD	S	S	N	N	S
	BOD	S	S	N	S	S
	TR	S	S	N	N	S
	TVR	S	S	N	N	S
	DR	S	S	N	S	S
	O&G	S	N	N	N	N
WASHER	COD	S	S	N	S	N
	BOD	S	N	N	N	N
	TR	S	N	N	S	N
	TVR	S	N	N	S	N
	DR	S	N	N	S	N
	O&G	N	N	N	N	N
PRECHILLER	COD	S	S	N	N	N
	BOD	S	S	N	N	N
	TR	S	S	N	N	N
	TVR	S	S	N	N	N
	DR	S	S	N	N	N
	O&G	S	S	N	N	N
CHILLER	COD	S	S	N	N	S
	BOD	S	S	N	N	S
	TR	S	S	N	N	N
	TVR	S	S	N	N	N
	DR	S	S	N	N	N
	O&G	S	S	N	S	S

S = Significant at the 5% level

N = Not significant at the 5% level

Makeup rates 20,25,30, and 40m^3/d

Hours 1,2,3,4,and 5

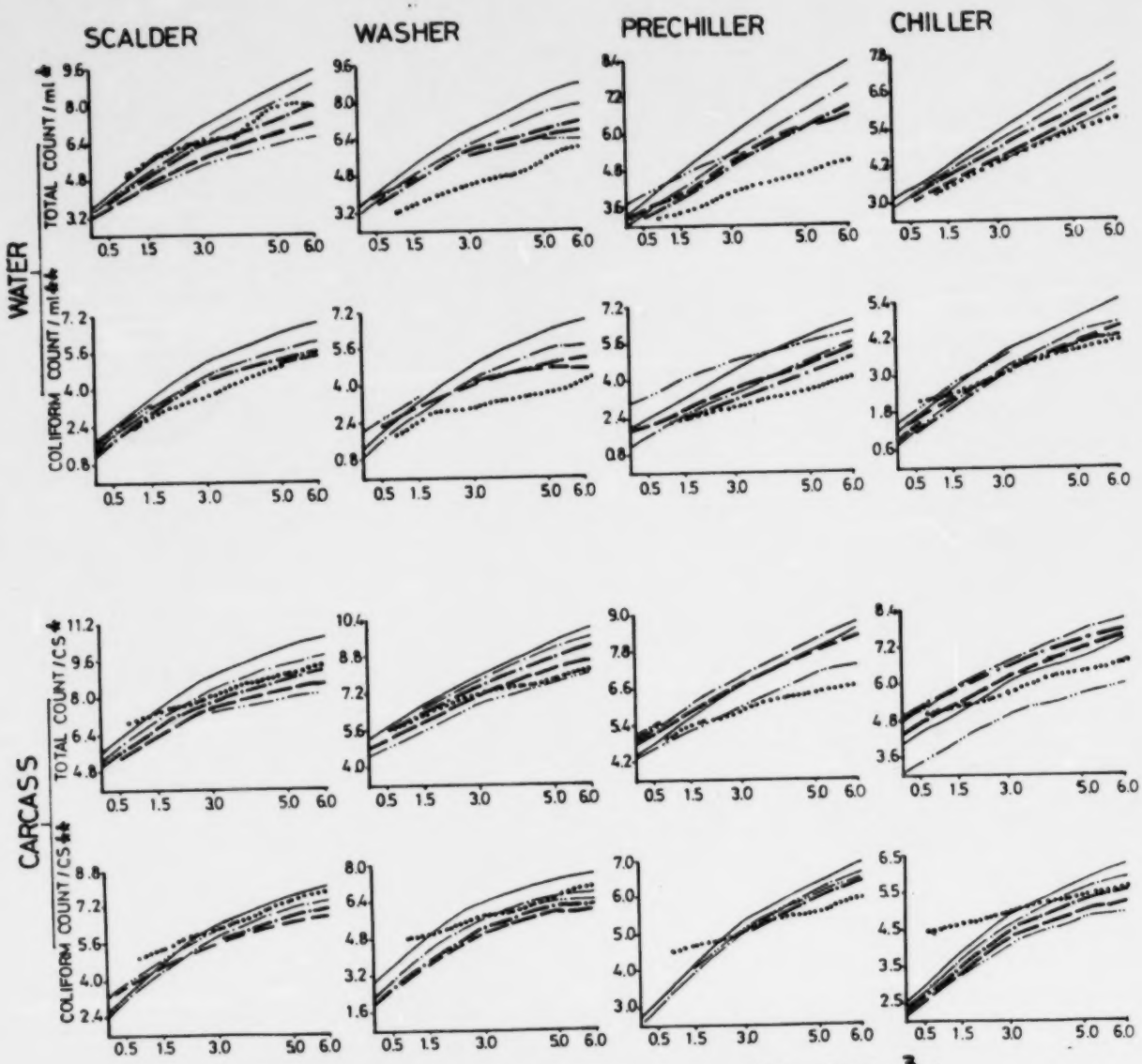


Figure 7. EFFECT OF WATER MAKEUP RATE ON BACTERIAL CHARACTERISTICS OF WATER AND CARCASSES IN THE MULTIPLE REUSE SYSTEM [PHASE II]

Table 9. EFFECT OF MAKEUP RATE AND OPERATING TIME ON THE BACTERIAL COUNTS OF CARCASSES AND REUSED NONRENOVATED WATER

PROCESS	COUNT	SOURCE					MEAN COUNT	C.V.
		MAKEUP (Q)	Q*Q	HOURS (H)	H*H	H*Q	Log_{10}	
SCALDER	TW	N	N	S	S	S	5.72	10.8
	CW	S	S	S	S	N	3.88	22.1
	TC	S	N	S	S	S	7.41	8.81
	CC	N	S	S	S	N	5.18	18.32
WASHER	TW	S	S	S	S	S	5.52	11.15
	CW	S	S	S	S	S	3.66	20.47
	TC	N	N	S	N	N	7.05	13.49
	CC	S	N	S	S	N	4.73	25.87
PRECHILLER	TW	N	N	S	N	S	4.70	12.94
	CW	S	S	S	S	N	2.94	22.92
	TC	S	S	S	N	N	5.88	16.71
	CC	N	N	S	S	N	4.08	27.73
CHILLER	TW	N	N	S	N	S	4.70	12.94
	CW	S	S	S	S	N	2.94	22.92
	TC	S	S	S	N	N	5.88	16.71
	CC	N	N	S	S	N	4.08	27.73

TW = LOG_{10} TOTAL AEROBIC COUNT OF WATER/ml

CW = LOG_{10} COLIFORM COUNT OF WATER/ml

TC = LOG_{10} TOTAL AEROBIC COUNT OF CARCASS

CC = LOG_{10} COLIFORM COUNT OF CARCASS

S = SIGNIFICANT AT THE 5% LEVEL

N = NOT SIGNIFICANT AT THE 5% LEVEL

C.V.= COEF OF VARIATION

MAKEUP RATES 20,25,30 AND 40 m^3/d

Table 10. EFFECT OF WATER MAKEUP RATE ON QUALITY OF CARCASSES AND PROCESSING WATER IN THE NORMAL ONCE-THROUGH AND NON-RENOVATED MULTIPLE REUSE SYSTEMS

Makeup Water m^3/d	#	S C A L D E R COD	BOD	TR	O&G	TW	CW	TC	CC	W A S H E R COD	BOD	TR	O&G	TW	CW	TC	CC
		(mean, mg/l)								(mean, mg/l)							
Normal[a]	5	1571*	1198*	1683*	89*	5.56*	4.60*	7.55*	6.40*	1588*	1284*	1832*	265*	4.83*	5.77*	7.15*	5.48*
20	3	2298S	1862S	2737S	81N	6.39N	4.35N	8.06N	5.29N	1385N	1044N	1990N	198S	6.21S	5.12N	7.56N	5.57N
25	3	1702S	1156N	1946N	69N	5.99N	3.97N	7.88N	5.28N	1350N	1114N	1541N	139S	5.48S	3.38N	7.19N	4.58N
30	2	1490N	1064N	1922N	98N	5.44N	2.75S	6.89N	4.86N	1166N	938N	1642N	197S	5.38S	3.30N	7.17N	4.17N
35	2	1701N	916N	2216N	52N	5.47N	4.08N	6.81N	5.13N	896S	987N	1271N	152S	4.80N	3.79N	6.87N	4.75N
40	2	1057N	1198N	1455N	87N	4.84N	3.73N	6.77N	5.38N	1216N	954N	1923N	154S	5.10N	3.50N	6.11S	4.16N

Makeup Water m^3/d	#	PRECHILLER COD	BOD	TR	O&G	TW	CW	TC	CC	CHILLER COD	BOD	TR	O&G	TW	CW	TC	CC
		(mean, mg/l)								(mean, mg/l)							
Normal	5,15[b]	1880*	1432*	2120*	245*	5.11*	3.04*	5.41*	4.39*	1314*	915*	1594*	217*	3.83*	2.69*	4.76*	3.98*
20	3	826S	685S	1166S	126S	5.69N	4.31S	6.23S	4.71N	667S	575S	831S	176N	5.17S	3.36S	5.73N	4.41N
25	3	973S	765S	1143S	86S	5.14N	2.97N	6.95S	4.81N	438S	528S	682S	64S	4.72S	2.60N	6.46S	4.16N
30	2	751S	604S	1226S	115S	4.77N	2.81N	6.73S	4.22N	519S	400S	784S	110S	4.74S	2.34N	6.37S	3.90N
35	2	647S	530S	882S	97S	4.95N	3.52N	5.97N	4.58N	482S	417S	568S	66S	4.34N	3.03N	6.02N	4.05N
40	2	548S	415S	822S	82S	5.09N	4.30S	5.34N	4.67N	359S	238S	679S	85S	4.33N	3.00N	4.59N	3.59N

TW= Log_{10} Total aerobic count of water/ml

CW= Log_{10} Coliform count of water/ml

TC= Log_{10} Total aerobic count/carcass

CW= Log_{10} Coliform count/carcass

#= No. of samples.

S= Significant at the 5% level

N= Not significant at the 5% level

* Control

a Normal makeup rate for the washer and chillers averages 43.7 m^3/d

b No. of samples for TW and CW in the prechiller and chiller.

increases in O&G and aerobic counts in washer water from the multiple water reuse system. The volume of makeup water in the multiple reuse (Phase II) was not appreciably different from normal once-through system (see Table 7) and may account for the similarity in level of pollutants and bacterial counts in both water use systems (Phase I and II).

3- In the prechiller, the effect of the water reuse system was erratic. Water reuse at makeup rates of 20,25,30, 35, and 40 m^3/d produced significant decreases in the concentration of pollutants, probably due to a dilution factor. The increase in water makeup rate (see Table 7) was associated with progressive decreases in concentration of COD, BOD and TR. However, the multiple water reuse system (Phase II) did not result in microbiological improvements in water or carcass quality. At this particular plant an increase in water temperature of 5-6°c above normal operating temperatures was experienced due to the lack of ice needed to cool the excessive amount of chilling water used in the multiple reuse system (see Table 7). This increase in temperature may be partially responsible for the higher bacterial counts.

4- In the chiller the chemical quality of water improved significantly in the multiple reuse system (Phase II) compared to the normal system (Phase I), probably due to a dilution factor when the water makeup volume was increase from 7 m^3/d to between 20 and 40 m^3/d.
Bacterial quality of water in the chiller was significantly worse in the multiple reuse system, probably due to the increase in chiller water temperature.

Bacterial counts for carcasses from the chiller were higher in the reuse system than in the non-reuse system, the mean values were not statistically different in most instances, probably due to the small number of observations.

It was concluded that further treatment of processing water is necessary in the multiple reuse system in order to control bacterial levels on carcasses and in chill water. A system for continuous chlorination of makeup water was instituted in the next phases of these studies.

EFFECT ON PROCESSING WATER AND CARCASSES OF USING COMPRESSOR WATER IN LIEU OF POTABLE WATER FOR FRESH WATER INPUT

Two comparisons were made in evaluating the effect of using compressor water for input water: (1) the chemical and bacterial characteristics of both potable and compressor water at the point of input to the process;and(2) the effect of both water sources on the quality of both processed carcasses and immersion water used in the chiller, prechiller,washer and scalder.

The summary of chemical and bacterial characteristics of both water sources, and results of the analysis of variance are presented in Table 11.

The pH of the compressor water is slightly higher than that of fresh water but both meet the pH 7.0-8.5 international standard set for drinking water[18]. Levels of chlorides, calcium, magnesium, carbonates, sulfates, nitrates and silica are similar in both water sources. The 378 mg/L TR in compressor water was significantly higher than the 308 mg/L in fresh water, but still lower than the highest desirable level of 500 mg/L[18]. COD was also significantly higher in compressor than fresh water, but is also a relatively low value and would not be expected ot pose a problem.

The relatively high concentration of ammonia -N (36mg/L) in compressor water is of concern. Ammonia in fresh water usually results from the breakdown of nitrogenous matter. However, the basic source of ammonia in compressor water was probably due to a leakage in the cylinders during the initial period of operation.

Since ammonia reacts with chlorine to form chloramines, excessive levels of ammonia could reduce the bactericidal effectiveness of chlorine in processing water. Attention was given to the leakage problem and frequent monitoring during later experiments indicated that ammonia levels were consistently less than 10 mg/L in compressor water.

The concentration of trace metals in compressor water was nearly identical to concentrations in potable water (Table 4). Total aerobic counts were higher in compressor than in fresh water, but were not so high as to cause concern. Coliforms were not recovered from either water source (Table 11).

Table 11. CHEMICAL AND BACTERIAL CHARACHTERISTIES OF DRINKING WATER AND COMPRESSOR COOLING WATER

		DRINKING WATER[a]	COMPRESSOR WATER[b]	
pH		7.4	7.7	S
CHLORIDES	mg/l	54.0	54.0	N
CALCIUM	mg/l	34.0	34.0	N
MAGNISUM	mg/l	15.3	16.0	N
CARBONATES	mg/l	81.2	80.0	N
SULFATES	mg/l	38.5	39.0	N
NITRATES-N	mg/l	4.6	5.0	N
AMMONIA-N	mg/l	3.9	36.0	S
SILICA	mg/l	12.1	12.3	N
TR	mg/l	308	378	S
COD	mg/l	12	30	S
TOTAL COUNT/ml		16	110	S
COLIFORM COUNT/100 ml		-	-	

a) Average for 12 Samples.

b) Average for 30 Samples.

S = Significant differences at the 5% level.

N = Not significant at the 5% level

These results indicate that compressor water is suitable for reuse as makeup water in the immersion processes. Therefore, compressor water was substituted for potable makeup water in the chlorination studies (Phase IV, TRT B).

Table 12 comares organic loading of processing water in the immersion tanks when fresh water input (TRT A) and compressor water input (TRT B) was used. Comparisons were made at 1 and 3 hours after startup and at two water rates(10 and 20 m^3/d^1) and one cholrination level (20 mg/L) In most insttances when levels of organic matter in processing water were significantly higher between treatments, the higher levels occured when potable input water was used.

Analysis of variance using gerneral linear models shows the effect of treatments (A and B), operating conditions (water makeup rates and chlorine doses), and processing time on bacterial counts of carcasses and water (Table 13). There was a significant increase in total aerobic counts and coliform levels across hours of processing for both water and carcasses. No other significant differences were found in bacterial levels on carcasses except that carcasses from TRT B(compressor makeup water)had significantly higher coliform levels than TRT A (Potable makeup water) in the prechiller. TRT B resulted in significantly higher coliform counts in water from the prechiller and chiller. Since coliforms were not isolated from either potable or compressor water prior to processing, these differences may be attributed to differences in flocks and number of carcasses processed for each treatment treatment. It was concluded that using water from the compressors in lieu of potable water for makeup would not have a deleterious effect on product.

EFFECTS OF MAKEUP RATES AND CHLORINE DOSE ON CHEMICAL QUALITY OF WATER

The effect of water rate and chlorine dose on chemical quality of immersion water with input from the compressors water (TRT B) is shown in Table 14 and Figure 8. With minor exceptions, increasing the water makeup rate between 10 and $30m^3/d$ significantly reduced the level of pollutants and their rate of accumulation as indicated by the general decrease in slope of the lines for makeup rate of 30 m^3/d (Figure 8). The effect of chlorination on chemical parameters was evaluated at a constant water input rate of 20 m^3/d (Figure 9). The ANOVA shown in Table 15 indicates that, with some exceptions, chlorine levels had no significant effect on chemical characteristics of process waters.

EFFECT OF MAKEUP RATES AND CHLORINE DOSE ON BACTERIAL COUNTS

Table 16 and Figure 10 show that water makeup rate had no significant effect on bacterial levels in the scalder. This is expected as the water rate in the scalder is constant. In washer and

Table 12. MEANS FOR CHEMICAL PARAMETERS OF PROCESS WATER IN TREATMENTS A AND B[a] (Phases III and IV)
(mg/l)

PROCESS	HOUR	TRT	COD		TR		TVR	
SCALDER								
Rate=10^3/d	1	A	1700	S	2294	S	1710	S
Cl_2 dose=20mg/l		B	1593		1870		1375	
	3	A	2500		3038		2311	
		B	2432		3090		2395	
Rate=20 m^3/d	1	A	1646		1918		1315	
Cl_2 dose=20 mg/l		B	1556		1879		1398	
	3	A	2509	S	2731	S	1965	S
		B	2221		3164		2424	
WASHER								
Rate=10 m^3/d	1	A	482		1488		1068	
Cl_2 dose=20 mg/l		B	516		1352		908	
	3	A	838		212o		1390	
		B	835		1930		1333	
Rate=20 m^3/d	1	A	459		1427	S	933	
Cl_2 dose=20 m^3/d		B	505		1316		885	
	3	A	825		2120	S	1410	S
		B	823		1894		1303	
PRECHILLER								
Rate = 10 m^3/d	1	A	342		780		348	S
Cl_2 dose= 20 mg/l		B	309		690		278	
	3	A	498	S	1050	S	584	
		B	412		993		603	
Rate=20 m^3/d	1	A	302		7o3		398	
Cl_2 dose=20mg/l		B	294		686		366	
	3	A	401		1007		496	S
		B	395		982		577	
CHILLER								
Rate = 10 m^3/d	1	A	202		583	S	243	
Cl_2dose=20 mg/l		B	189		478		261	
	3	A	494	S	898	S	446	S
		B	402		765		343	
Rate= 20 m^3/d	1	A	166		499		265	S
Cl_2 dose= 20 mg/l		B	173		426		197	
	3	A	425	S	814		347	
		B	351		826		381	

S = Significant differences between A & B at the 5% level
Trt A = Potable fresh water input plus Cl_2
Trt B = Compressor water input plus Cl_2

Table 13. EFFECT OF TREATMENT A AND B ON BACTRIAL COUNTS OF CARCASS AND PROCESS WATER

CARCASS

SOURCE	D.F.	SCALDER		WASHER		PRECHILLER		CHILLER	
		LOGT	LOGC	LOGT	LOGC	LOGT	LOGC	LOGT	LOGC
TREATMENT(T)	1	N	N	N	N	N	S	N	N
OP. COND(O)	2	N	N	N	N	N	N	N	N
T*O	2	N	N	N	N	N	N	N	N
HOURS (H)	4	S	S	S	S	S	S	S	S
T*H	4	N	N	N	N	N	N	N	N
O*H	8	N	N	N	N	N	N	N	N
T*O*H	8	N	N	N	N	N	N	N	N
MEANS Trt.A		4.79	3.45	4.18	3.24	4.42	3.38	4.35	3.38
COUNT/Ca Trt.B		5.36	4.38	5.72	4.33	5.34	4.25	4.78	3.66

PROCESS WATER

TREATMENT	1	N	N	N	S	N	S	N	S
OP. COND	2	N	N	N	N	N	N	N	N
T*O	2	N	N	N	N	N	N	N	N
HOURS	4	S	S	S	S	S	S	S	S
T*H	4	N	N	N	N	N	N	N	N
O*H	8	N	N	N	N	N	N	N	N
T*O*H	8	N	N	N	N	N	N	N	N
MEANS Trt.A		4.45	3.19	3.41	2.51	3.72	2.75	3.36	2.69
COUNTS/ml Trt.B		4.54	3.51	4.89	4.05	4.24	3.44	3.96	3.05

S = Significant at the 5% level

N = Not significant at the 5% level

LOGT= Log_{10} Total aerobic count/ml or carcass

LOGC = Log_{10} Coliform count/ml or carcass

Treatment A= Potable water input plus Cl_2

Treatment B= Compressor water input plus Cl_2

Hours =0.5,1.5,3,5 and 6

Makeup rate 10,20 and 30 m^3/d

Chlorine dose 10,20,30,40 and 50 mg/l

Table 14. EFFECT OF WATER INPUT RATE AND PROCESSING TIME ON CHEMICAL CHARACTERISTICS OF PROCESS WATER[a]

PROCESS	PARAMETER	HOURS(H)	RATE(Q)	H*H	Q*Q	Q*H
SCALDER	COD	S	S	N	S	S
	BOD	S	S	N	S	S
	TR	S	S	N	S	S
	VR	S	S	N	S	S
	DR	S	S	N	S	S
	O&G	S	S	N	S	S
WASHER	COD	N	S	S	S	S
	BOD	S	S	N	S	S
	TR	S	S	N	S	S
	VR	N	S	N	S	S
	DR	S	S	N	S	S
	O&G	S	S	N	S	S
PRECHILLER	COD	N	S	N	S	N
	BOD	N	S	S	S	N
	TR	N	S	N	S	S
	VR	N	S	N	S	S
	DR	S	S	N	S	S
	O&G	N	S	N	S	S
CHILLER	COD	S	S	N	S	S
	BOD	S	S	N	S	S
	TR	N	S	N	S	N
	VR	S	S	N	S	S
	DR	N	S	N	S	N
	O&G	S	S	N	S	S

a) Makeup Rates: 10,15,20,.and 30 m^3/d Hours:1,2,3,4,and 5

No. of experiments = 12

Data pooled for all chlorine levels (10-50 mg/1).
Significance is reported at the 5% level.

S = Significant
N = Not significant

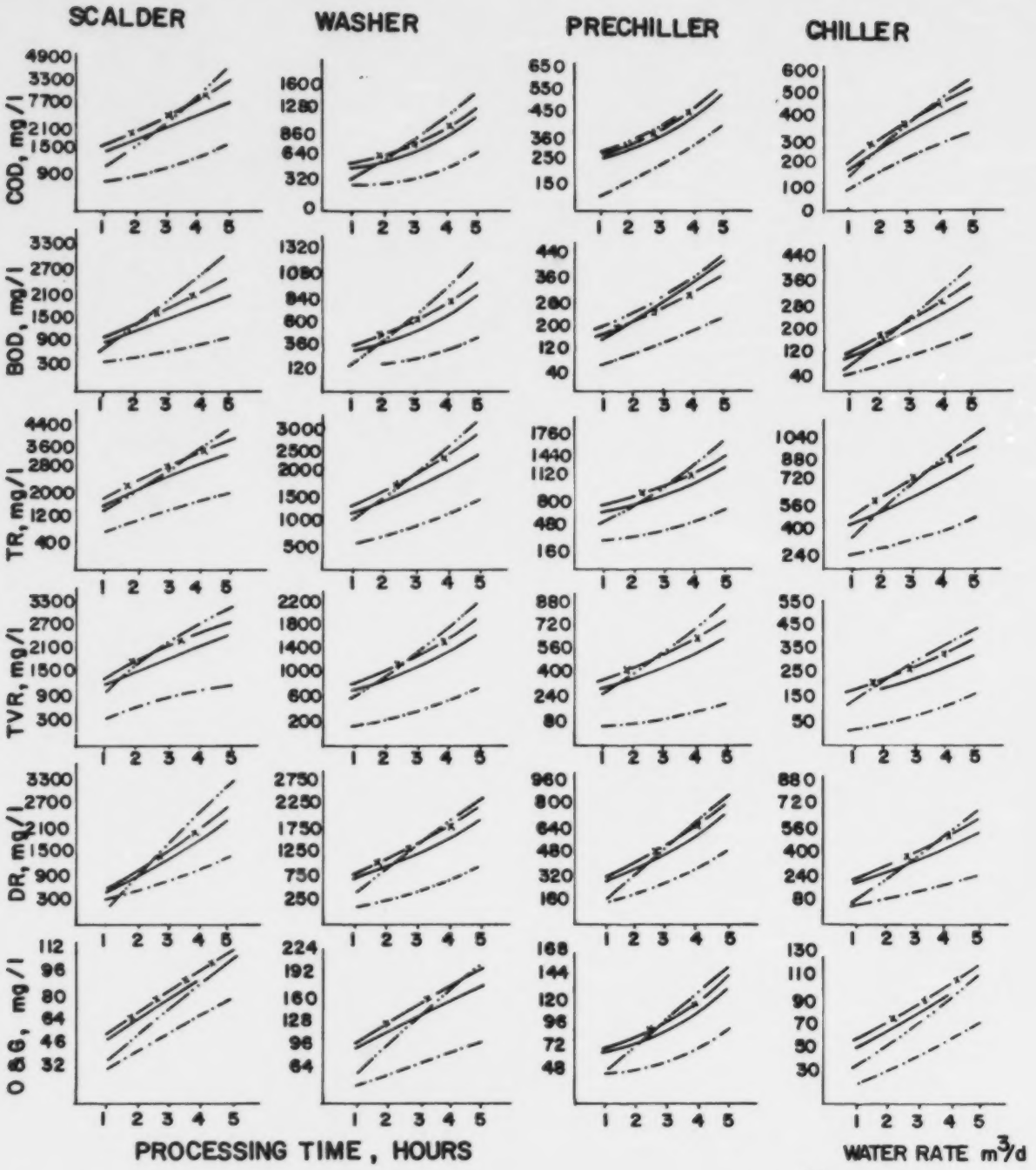


Figure 8. EFFECT OF WATER MAKEUP RATE ON ORGANIC LOADING OF PROCESSING WATER IN THE MULTIPLE REUSE SYSTEM (TRT B) [Data pooled for chlorine doses 0-50 mg/l]

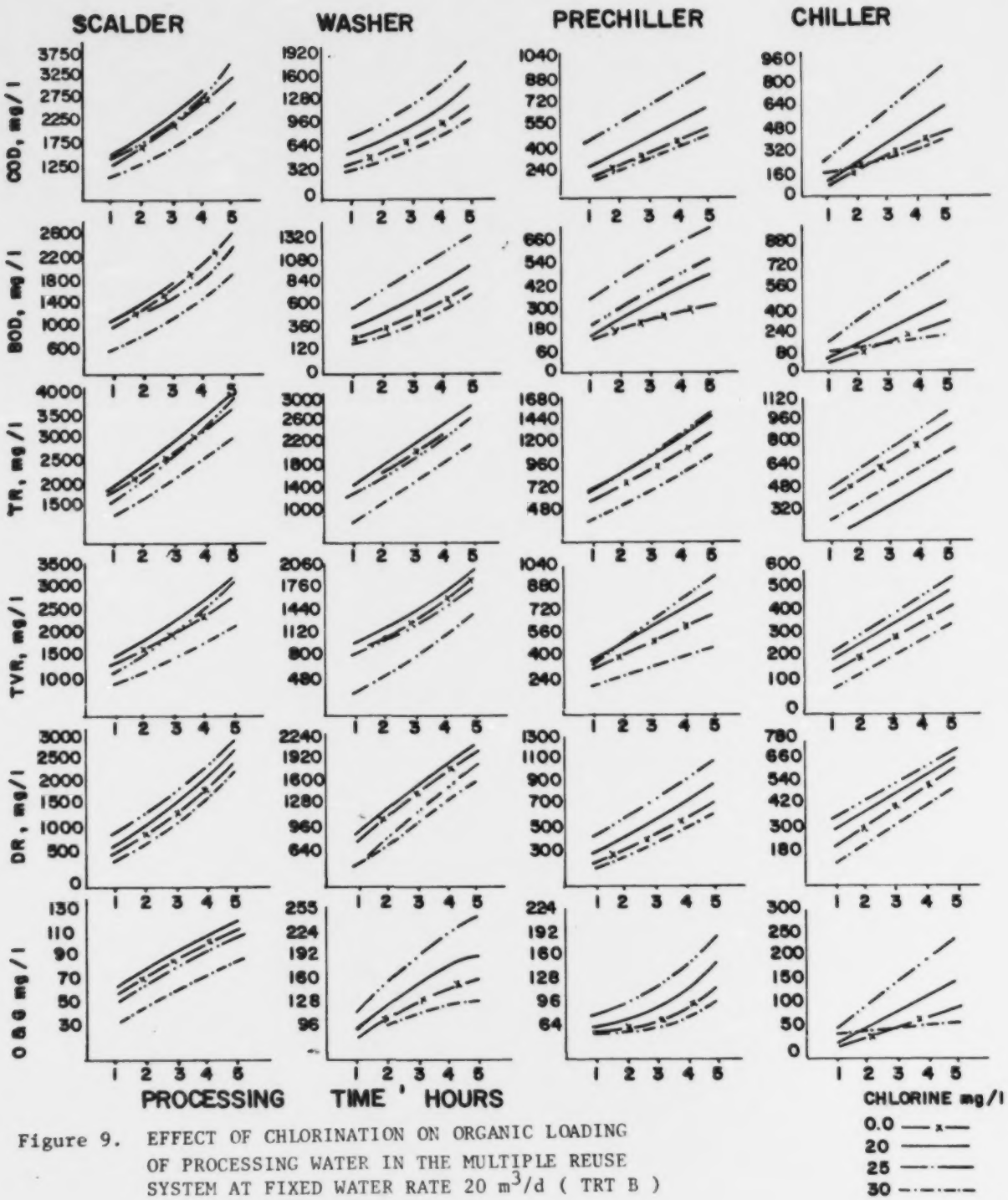


Figure 9. EFFECT OF CHLORINATION ON ORGANIC LOADING OF PROCESSING WATER IN THE MULTIPLE REUSE SYSTEM AT FIXED WATER RATE 20 m^3/d (TRT B)

Table 15. EFFECT OF CHLORINATION ON CHEMICAL CHARACTERISTICS OF PROCESS WATER (TRT=B)[a]

PROCESS	PARAMETER	SOURCE				
		Hours (H)	Cl_2	H*H	Cl_2*Cl_2	Cl_2*H
SCALDER	COD	S	S	N	N	N
	BOD	S	S	N	N	N
	TR	S	S	N	S	N
	TVR	S	S	N	S	N
	DR	S	S	N	N	N
	O&G	S	S	N	S	N
WASHER	COD	S	S	N	N	N
	BOD	S	S	N	N	N
	TR	S	S	N	S	N
	TVR	S	S	N	S	N
	DR	S	S	N	N	N
	O&G	S	S	N	N	N
PRECHILLER	COD	S	S	N	N	N
	BOD	S	S	N	N	N
	TR	S	S	N	N	N
	TVR	S	S	N	N	N
	DR	S	S	N	N	N
	O&G	S	S	S	N	S
CHILLER	COD	S	S	N	S	S
	BOD	S	S	N	S	S
	TR	S	S	N	N	N
	TVR	S	S	N	N	N
	DR	S	S	N	N	N
	O&G	S	S	N	N	S

a) Analysis of variance at constant makeup rate of 20 m^3/d
S = Significant at the 5% level.
N = Not significant at the 5% level.
The significance values for H and Cl_2 are for the linear effect ignoring quadratic and cross-product effects.

Table 16. EFFECT OF WATER MAKEUP RATE AND PROCESSING TIME ON BACTERIAL COUNTS OF WATER AND CARCASS[a] (TRT B)

PROCESS	COUNTS	Q	Q^2	H	H^2	H*Q
SCALDER	LOGTW	N	N	N	N	N
	LOGCW	N	N	S	N	S
	LOGTC	N	N	N	N	N
	LOGCC	N	N	N	N	N
WASHER	LOGTW	S	S	S	N	N
	LOGCW	S	S	S	N	N
	LOGTC	N	S	N	N	N
	LOGCC	S	S	N	N	N
PRECHILLER	LOGTW	S	S	S	N	N
	LOGCW	S	S	S	N	N
	LOGTC	S	S	S	N	N
	LOGCC	S	S	S	N	N
CHILLER	LOGTW	S	S	S	N	N
	LOGCW	S	S	S	N	N
	LOGTC		N	S	N	N
	LOGCC	N	N	S	N	N

a) Makeup Rates 10,20 and 30 m^3/d, Processing Time 0.5,1.5,3,5 and 6 hours. Results Pooled for all Cl_2 levels.(10-50 mg/1). No. of Experiments = 11

S= Significant at the 5% level

N= Not significant at the 5% level

LOGTW = Log_{10} Total aerobic Count in water/ml

LOGCW = Log_{10} Coliform count in water/ml

LOGTC = Log_{10} Total aerobic count per carcass

LOGCC = Log_{10} Coliform count per carcass

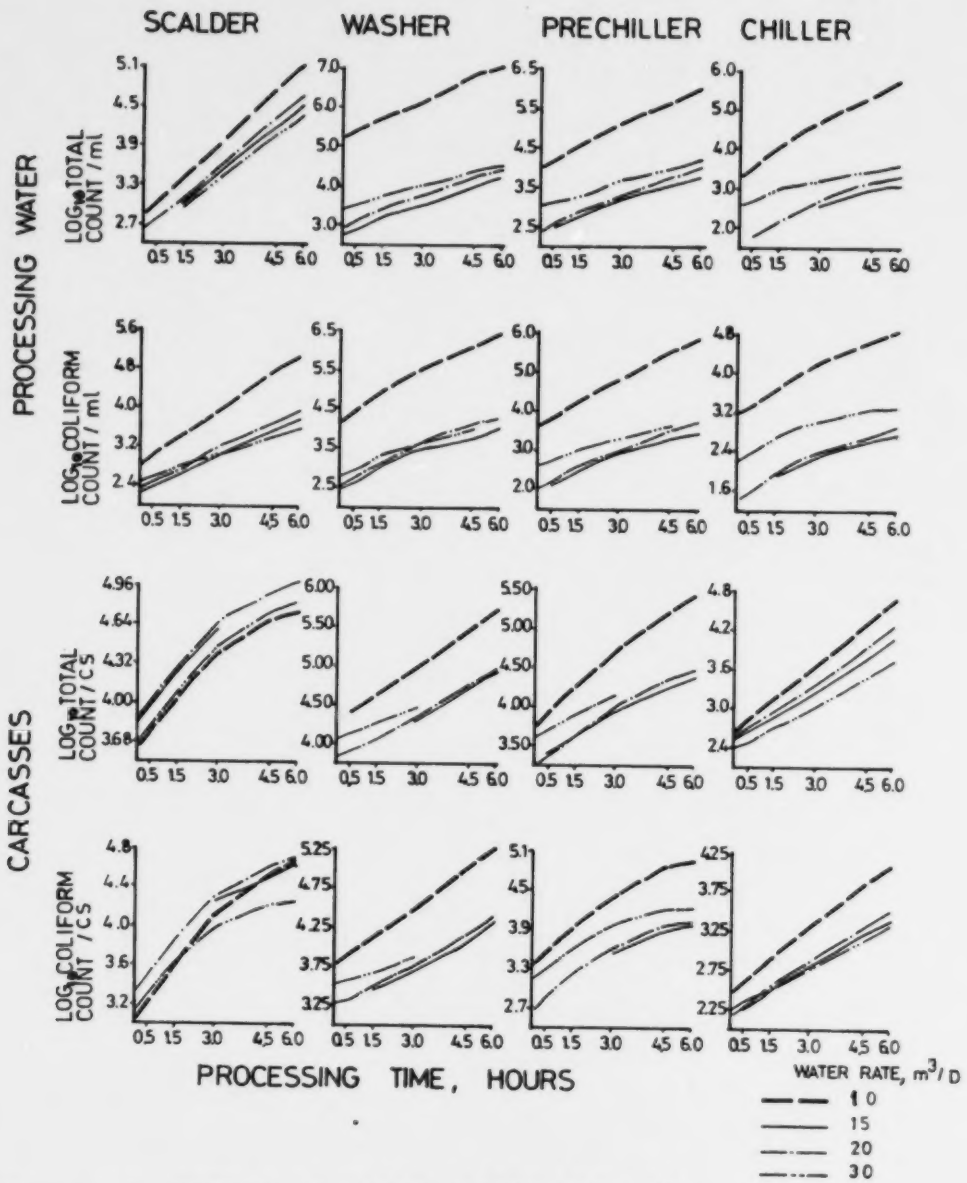


Figure 10. EFFECT OF WATER MAKEUP RATE ON BACTERIAL COUNTS OF WATER AND CARCASSES IN THE MULTIPLE REUSE SYSTEM (TRT B).

[Data pooled for chlorine dose 0-50 mg/l]

chillers both the water makeup rate and processing time showed effect on bacterial levles of the immersion water. However, few exceptions were noted as shown in Table 16.

A separate analysis of variance for the water makeup rates of 20 and 30 m^3/d indicated no significant differences at the 5% level in total aerobic and coliform counts for carcasses or water from any of the immersion tanks. The similarity of the counts of these makeup rates can be seen in Figure 10. However, it cannot be concluded that an optimum input rate exists since data for all chlorination levels (10 - 50 mg/l) were pooled in this analysis. Greater differences in bacterial levels may have been observed at water input rates of 20 and 30 m^3/d had chlorine been omitted.

The effect of chlorination on the magnitude and rate of accumulation of bacterial counts is shown in Table 17 and Figure 11, respectively. In all cases, bacterial levels in water decreases significantly as chlorine levels were increased, but rates of bacterial accumulation expressed as $\Delta \log C/\Delta T$ were similar in the scalder,washer and prechiller at the various chlorine doses. In most instances there was a significant increase in bacterial counts in water with time, probably due to the decreased bactericidal effect of chlorine as it combined with increasing levels of organic matter. Similar increases in carcass counts with time were noted in the multiple water reuse system.

Figures 12 and 13 are the response surfaces of total aerobic and coliform counts for processing water from the four immersion tanks in TRTs A and B.

Increasing the chlorine dose was effective in reducing bacterial counts. However, increasing the water makeup rate to 30 m^3/d led to increase in water temperature and therefore, to increase in bacterial counts. Water temperature in the chiller at high makeup rates (30 m^3/d) increased from 8.6°c to about 14.6°c for lack of ice. This probably accelerated the rate of bacterial growth. The washer water was less susceptible to temperature variations than chiller water; therefore, the gradual increase in water makeup rate was associated with an improvement in bacterial quality. The response surfaces shown in Figure 12 clearly demonstrate the favorable effect of increasing the chlorine dose on the bacterial counts of water. In almost all cases the optimum response (lowest bacterial level) was achieved with a chlorine dose of 22 mg/l and water makeup rate of 26 m^3/d. However, further increase of chlorine dose and water makeup rate was not accompanied by appreciable improvement in the bacterial quality

In general, both total and coliform counts responded in the same manner to the makeup rate and chlorine dose.

Table 17. EFFECT OF CHLORINE DOSE AND PROCESSING TIME ON BACTERIAL COUNTS OF WATER AND CARCASS
(TRT B)

PROCESS	COUNTS	Cl_2	Cl_2*Cl_2	HOURS(H)	H^2	Cl_2*H
SCALDER	Log TW	S	N	S	N	N
	Log CW	S	S	S	N	S
	Log TC	S	S	S	N	N
	Log CC	S	S	S	N	N
WASHER	Log TW	S	N	S	N	N
	Log CW	S	N	S	N	N
	Log TC	S	S	S	N	N
	Log CC	N	N	S	N	N
PRECHILLER	Log TW	S	S	S	N	N
	Log CW	S	S	S	N	N
	Log TC	S	S	S	N	N
	Log CC	N	N	S	N	N
CHILLER	Log TW	S	N	S	N	N
	Log CW	S	N	S	N	N
	Log TC	N	N	S	N	N
	Log CC	N	N	S	N	N

Cl_2 Dose 0,10,20,30,40 and 50 mg/l

Processing time 0.5,1.5,3,5 and 6 hours.

Results Pooled for Makeup Rate 10,15,20,30 m^3/d

No. of Experiments = 11

S Significant at the 5% Level

N Not Significant

$Log_{10}TW = Log_{10}$ Total Count in Water/ml

$Log_{10}CW = Log_{10}$ Coliform Count in Water/ml

$Log_{10}TC = Log_{10}$ Total Count of Carcass

$Log_{10}CC = Log_{10}$ Coliform Count of Carcass

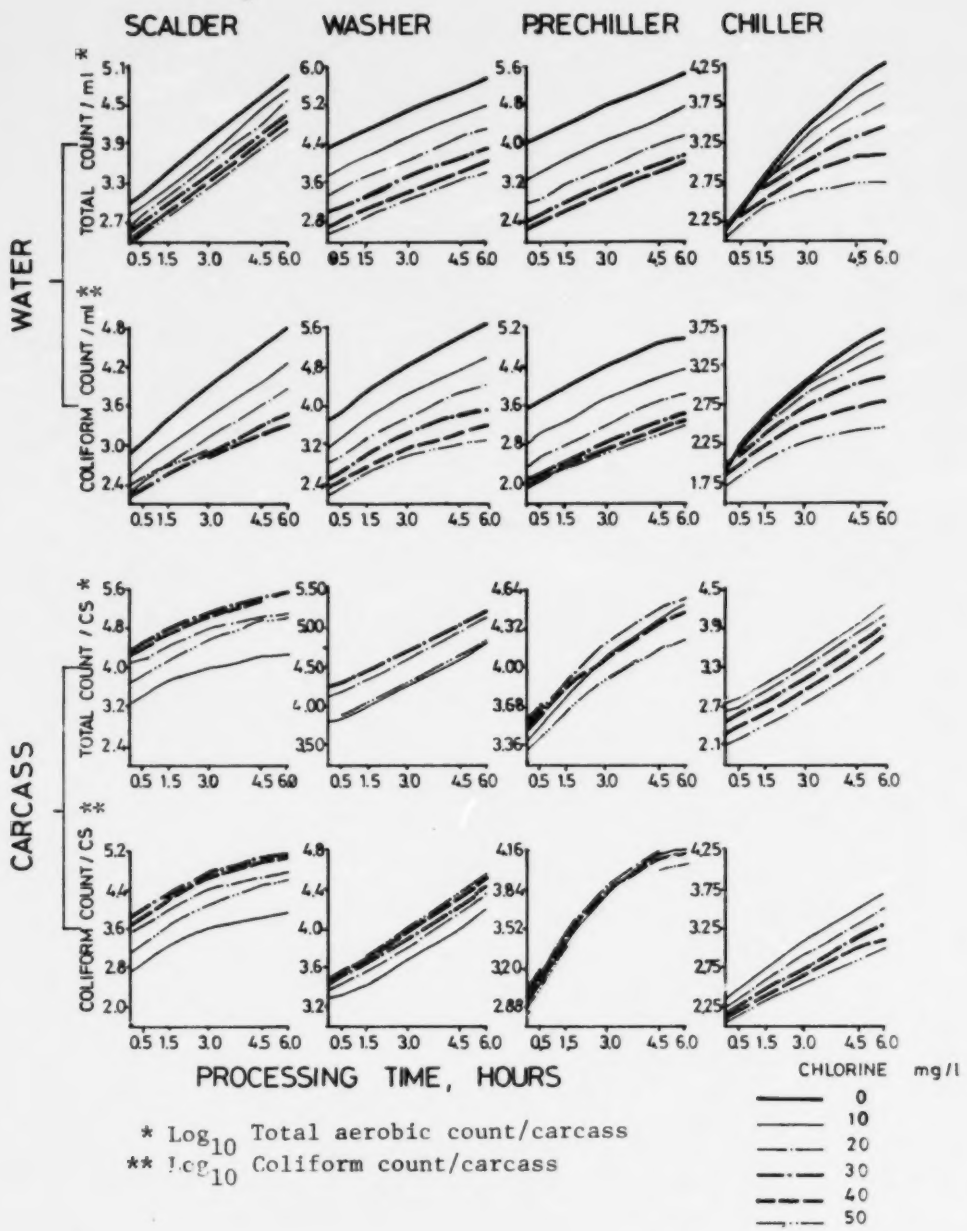
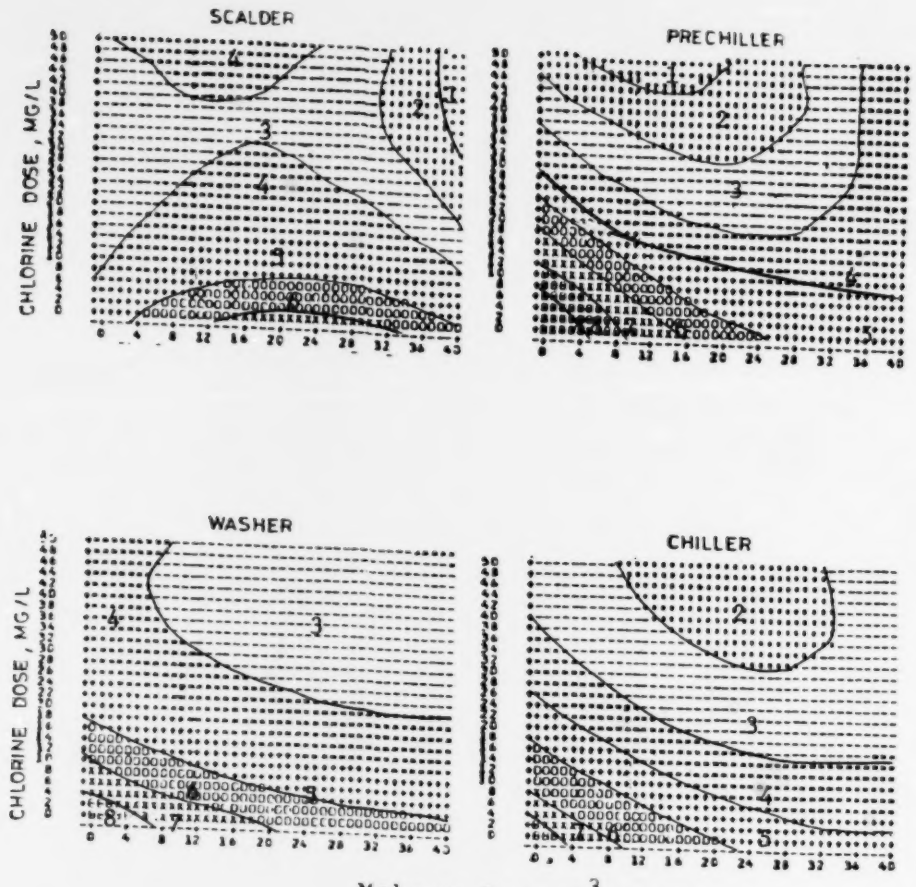
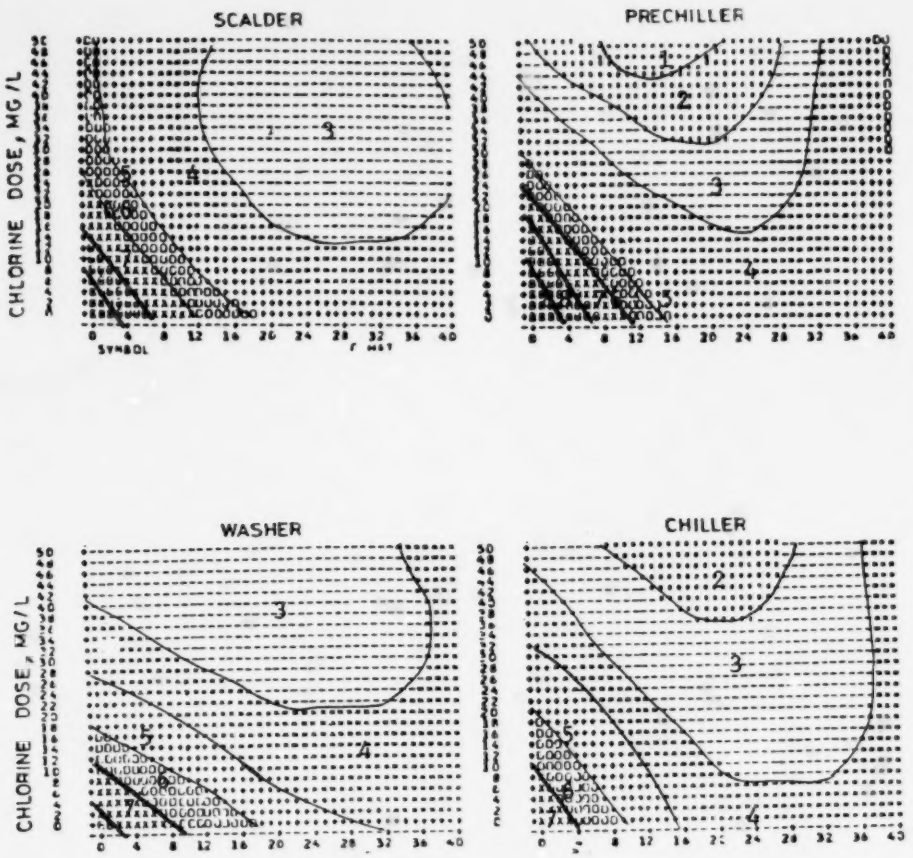


Figure 11. EFFECT OF CHLORINATION ON BACTERIAL COUNTS OF WATER AND CARCASSES IN THE MULTIPLE REUSE SYSTEM (TRT B)
[Data pooled for makeup rate 10-30 m^3/d]



Log_{10}	Count / ml
1	1.35 – 1.87
2	1.87 – 2.92
3	2.92 – 3.97
4	3.97 – 5.02
5	5.02 – 6.06
6	6.06 – 7.11
7	7.11 – 8.15
8	8.15 – 9.20
9	9.20 – 10.24
10	10.24 – 10.77

Figure 12. RELATIONSHIP BETWEEN TOTAL AEROBIC COUNT OF WATER, MAKEUP RATE AND CHLORINE DOSE FOR TRTs A AND B COMBINED
[Data of the Fifth Hour after Startup]



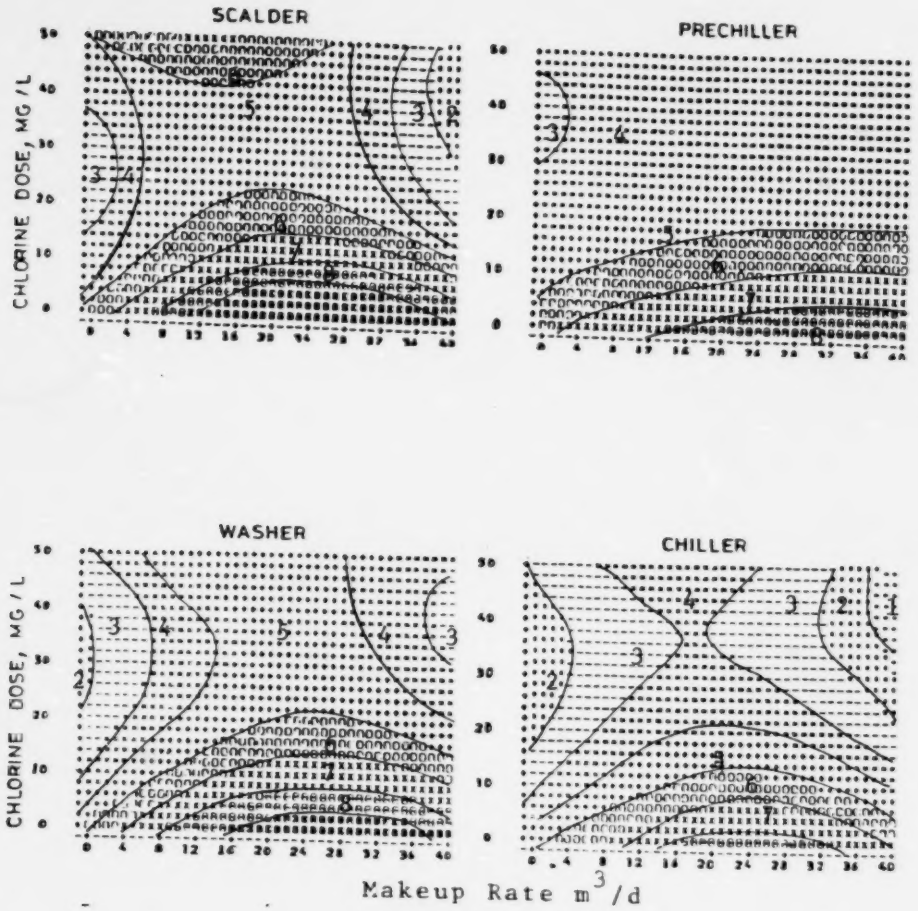
Log_{10}	Count / ml	Log_{10}	Count / ml
1	0.75 _ 1.31	6	5.80 _ 6.92
2	1.31 _ 2.44	7	6.92 _ 8.05
3	2.44 _ 3.55	8	8.05 _ 9.17
4	5.55 _ 4.68	9	9.17 _ 10.29
5	4.68 _ 5.80	10	10.29 _ 10.85

Figure 13. RELATIONSHIP BETWEEN COLIFORM COUNT OF WATER MAKEUP RATE AND CHLORINE DOSE FOR TREATMENTS A AND B COMBINED
[Data of the Fifth hour after Startup]

This is demonstrated by the similarity of their response surfaces at various operating conditions.

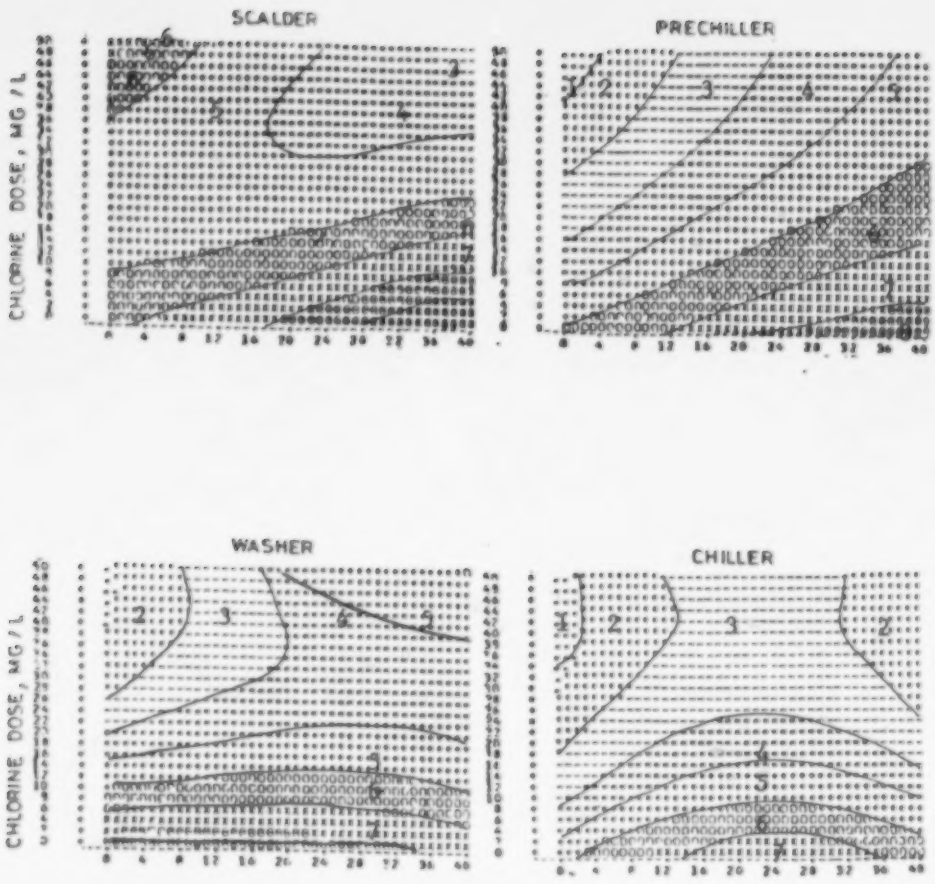
Figures 14 A and 14 B show the surface responses for carcass total aerobic and coliform counts, respectively. In most instances the carcass counts were not affected by the increase in the water makeup rate. The response in this case was function of chlorine dose rather than water makeup rate.

The response surfaces of Figures 14 A and 14 B demonstrate that effective reduction of bacterial counts of the carcasses in the washer and chillers can be achieved while using minimum makeup rates (0 - 5 m^3/d) and chlorine doses in the range of 15 to 20 mg/l. This implies that makeup waters needed for washing and chilling operations can be reduced without scarficing the quality of the processed carcasses if proper chlorination is applied in the multiple reuse system.



	Log_{10} Count/CS		Log_{10} Count/CS
1	1.39 – 1.79	6	5.04 – 5.85
2	1.79 – 2.61	7	5.85 – 6.66
3	2.61 – 3.42	8	6.66 – 7.47
4	3.42 – 4.23	9	7.47 – 8.28
5	4.23 – 5.04	10	8.28 – 8.60

Figure 14 - A RELATIONSHIP BETWEEN TOTAL AEROBIC COUNT OF CARCASSES, MAKEUP RATE AND CHLORINE DOSE FOR TREATMENTS A AND B COMBINED
[Data of the Fifth Hour After Startup]



Log_{10}	Count / cs
1	1.71 – 2.03
2	2.03 – 2.65
3	2.65 – 3.28
4	3.28 – 3.90
5	3.90 – 4.53
6	4.53 – 5.15
7	5.35 – 5.78
8	5.78 – 6.40
9	6.40 – 7.03
10	7.03 – 7.53

Figure 14 - B REIATIONSHIP BETWEEN COLIFORM COUNT OF CARCASSES, MAKEUP RATE AND CHLORINE DOSE FOR TREATMENTS A AND B COMBINED
[Data of the Fifth Hour After Startup]

RENOVATION OF PROCESSING WATER IN THE MULTIPLE REUSE SYSTEM

Water used for filling and makeup in the four immersion tanks was chlorinated. However, results indicated the need for renovation of processing water (removal of organic matter) in the multiple reuse system in order to enhance the bactericidal effect of chlorine. Therefore, water at selected points in the Multiple Reuse System (MRS) was renovated by filtering through diatomaceous earth in a closed loop system.

A randomized block design was used to compare the various renovation schemes. Three treatments (TRTs) were used with the MRS for this comparison:

i- TRT AB (chlorination of water without filtration: results combined from fresh water input (TRT A) and compressor water input (TRT B).

ii- TRT C (continuous filtration of the wash water).

iii- TRT D (continuous filtration of the water in the prechiller).

Three sets of operating conditions (OPCONS) were used with each of the three TRTs as follows:

i- OPCON 1 - water makeup rate of 10 m^3/d and chlorine dose of 10 mg/l.

ii- OPCON 2 - water makeup rate of 20 m^3/d and chlorine dose of 20 mg/l.

iii- OPCON 3 - water makeup rate of 20 m^3/d and chlorine dose of 30 mg/l.

Comparison of the MRS and the Normal Once-through Systems

Table 18 summarizes the chemical data of processing water for the normal once-through system and the three OPCONs for each of the three treatments AB, C and D. Figures 15 A, B, C and D illustrate the effects of the MRS with water renovation, and the normal system, on chemical characteristics of immersion waters.

1- The MRS produced significant reductions in the COD, BOD, TR and O&G of the processing waters in the chiller, prechiller and washer in comparison with the normal system. The increase in water chlorination (10,20,30 mg/l) for each of the three treatments resulted in decreases in the concentration of pollutants.

Table 18. CHEMICAL CHARACTERISTICS OF PROCESS WATER FROM THE NORMAL AND THE MULTIPLE WATER REUSE SYSTEM WITH RENOVATION

TRT	Water m^3/d	Cl_2 mg/l	n	SCALDER COD Mean mg/l		SCALDER BOD Mean mg/l		SCALDER TR Mean mg/l		SCALDER O&G Mean mg/l	
Normal			5	1571	*	1198	*	1683	*	89	*
AB	10	10	2	2409	S	1887	S	3015	S	78	N
	20	20	5	2475	S	1733	S	2882	S	82	N
	20	30	2	2024	S	1178	N	2427	S	134	N
C	10	10	5	2233	S	1847	S	2524	S	111	N
	20	20	5	1347	N	833	S	1624	N	103	N
	20	30	4	1289	N	779	S	1550	N	65	N
D	10	10	3	1952	N	1877	S	2655	N	126	N
	20	20	2	960	S	859	S	1673	N	117	N
	20	30	2	1900	N	1710	S	2511	S	71	N

WASHER COD Mean mg/l		WASHER BOD Mean mg/l		WASHER TR Mean mg/l		WASHER O&G Mean mg/l	
1588	*	1284	*	1832	*	265	*
902	S	688	S	2176	S	154	S
897	S	601	S	2153	S	165	S
698	S	423	S	1709	N	129	S
488	S	420	S	883	S	43	S
430	S	365	S	793	S	47	S
339	S	249	S	784	S	45	S
531	S	490	S	1199	S	150	S
537	S	488	S	1113	S	90	S
405	S	255	S	1118	S	86	S

TRT	Water m^3/d	Cl_2 mg/l	n	PRECHILLER COD Mean mg/l		PRECHILLER BOD Mean mg/l		PRECHILLER TR Mean mg/l		PRECHILLER O&G Mean mg/l	
Normal			5	1880	*	1432	*	2120	*	245	*
AB	10	10	2	449	S	296	S	1184	S	110	S
	20	20	5	430	S	288	S	1090	S	113	S
	20	30	2	360	S	229	S	877	S	77	S
C	10	10	5	448	S	349	S	102	S	106	S
	20	20	5	347	S	247	S	753	S	144	S
	20	30	4	342	S	236	S	606	S	70	S
D	10	10	3	240	S	219	S	758	S	40	S
	20	20	2	141	S	118	S	522	S	47	S
	20	30	2	141	S	97	S	373	S		

CHILLER COD Mean mg/l		CHILLER BOD Mean mg/l		CHILLER TR Mean mg/l		CHILLER O&G Mean mg/l	
1314	*	915	*	1594	*	217	*
417	S	248	S	808	S	89	S
366	S	237	S	745	S	98	S
322	S	183	S	610	S	71	S
332	S	276	S	741	S	104	S
291	S	240	S	736	S	143	S
313	S	215	S	731	S	87	S
382	S	304	S	778	S	151	S
177	S	163	S	501	S	91	S
88	S	76	S	368	S	51	S

S = Significant differences at the 5% level.
N = Not Significant differences at the 5% level.

n = Number of Samples

* = Control

AB Reuse of chlorinated water
C Reuse of chlorinated water & filtration of wash water.
D Reuse of chlorinated water & filtration of prechiller water.

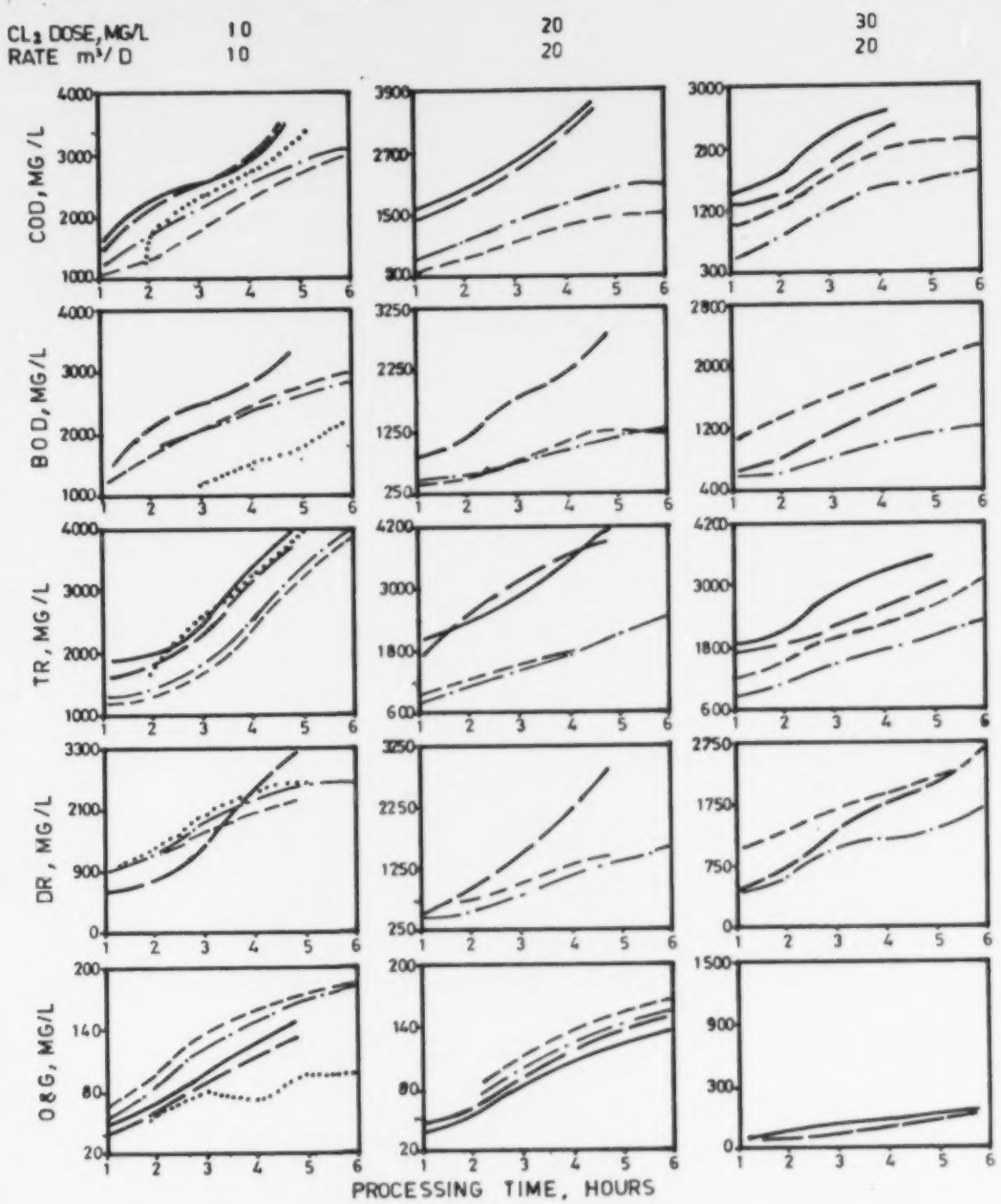


Figure 15-A. EFFECT OF TREATMENTS ON ACCUMULATION OF POLLUTANTS IN THE SCALDER

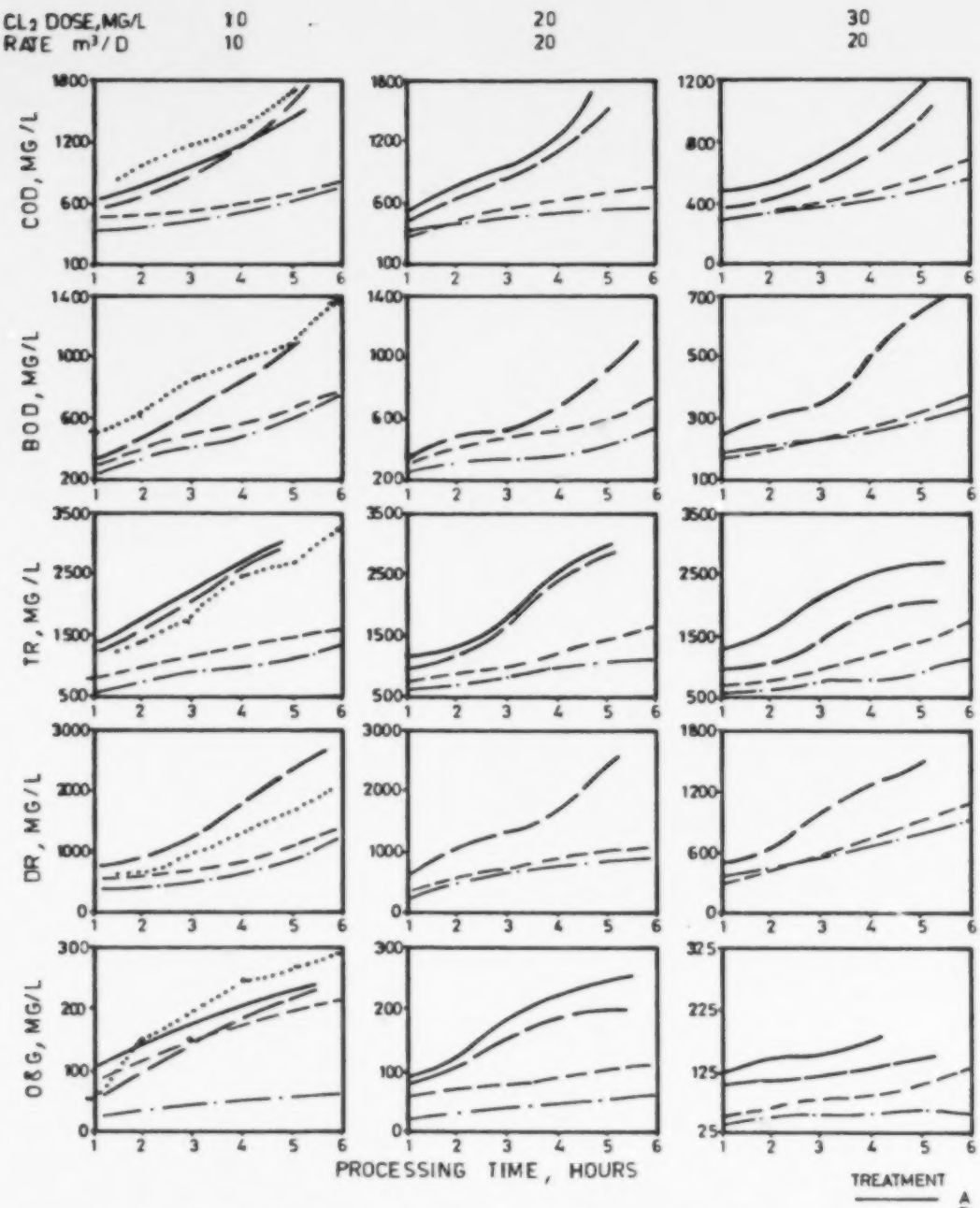


Figure 15-B. EFFECT OF TREATMENTS ON ACCUMULATION OF POLLUTANTS IN THE WASHER

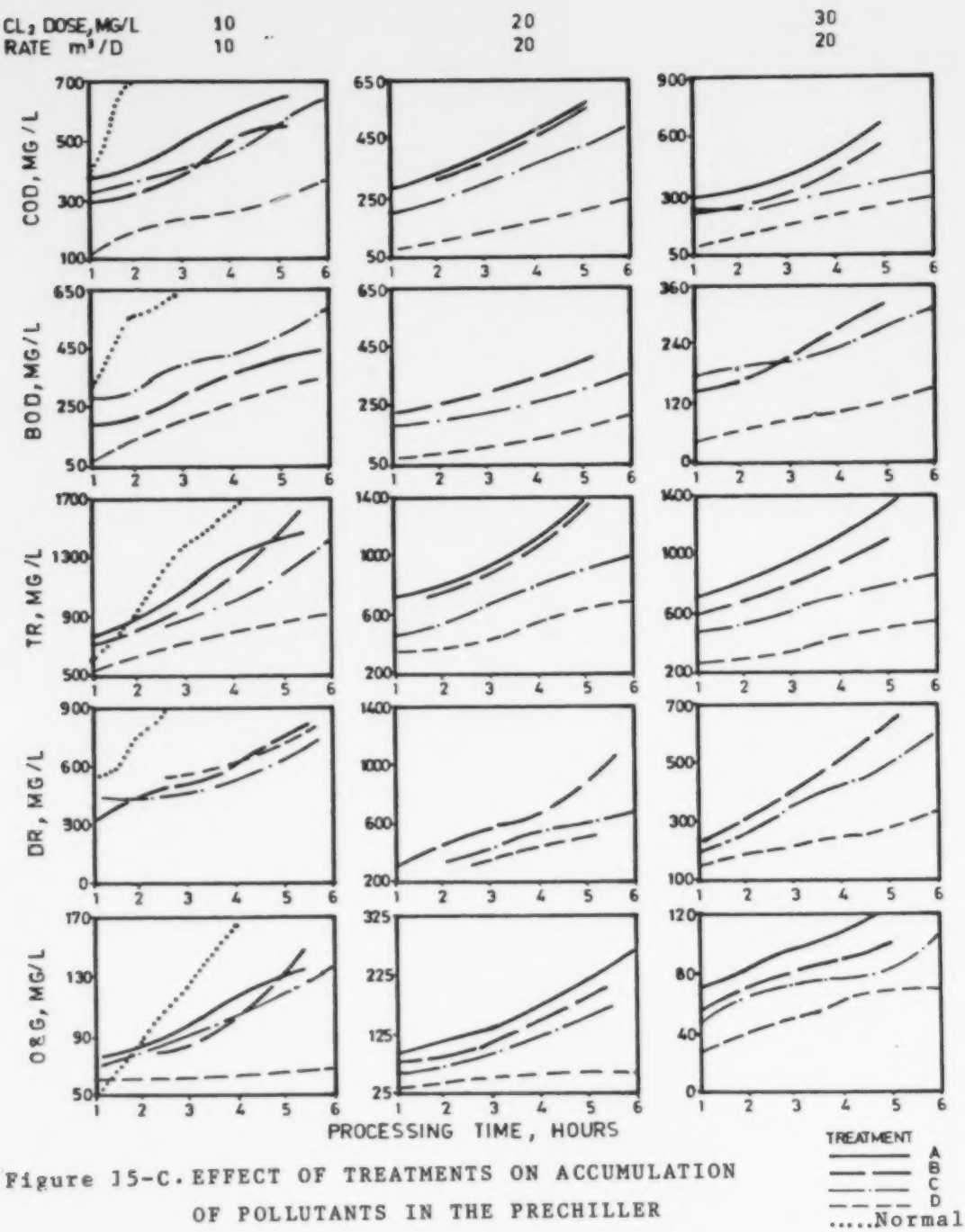


Figure 15-C. EFFECT OF TREATMENTS ON ACCUMULATION OF POLLUTANTS IN THE PRECHILLER

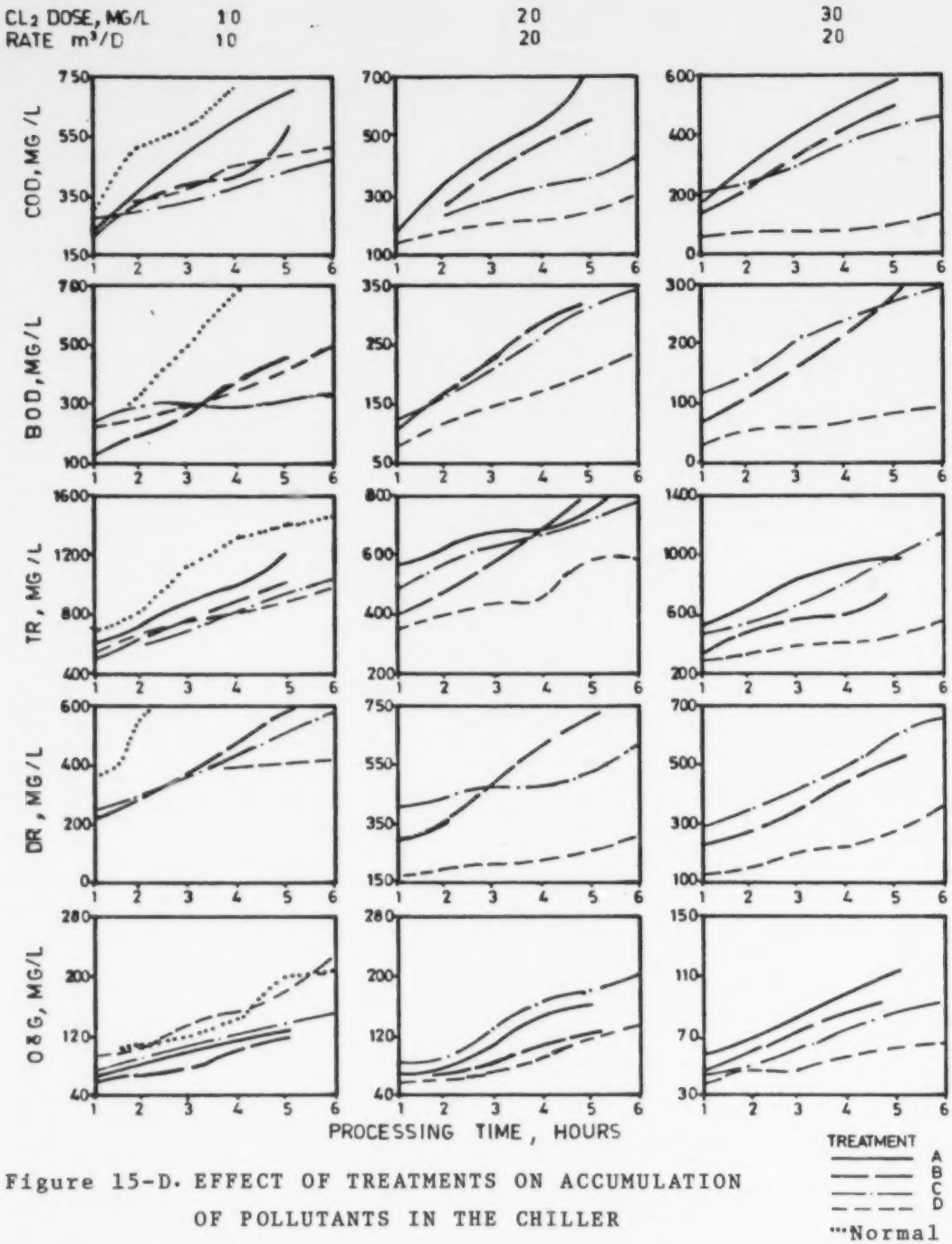


Figure 15-D. EFFECT OF TREATMENTS ON ACCUMULATION OF POLLUTANTS IN THE CHILLER

2- The MRS was instituted to conserve water. The use of makeup water at 10 and 20 m^3/d reduced water usage for makeup by 23% and 46% of normal consumption, respectively. Water conservation in the MRS resulted in improved quality of processing water due to removal of pollutants by filtration of washing and chilling waters.

3- Scald water did not improve significantly with the multiple reuse system. In some instances pollutants increased in scald water, probably due to the accumulation of pollutants in the wash water which was reused as makeup water in the scalder.

The effect of the normal system and the MRS on geometric mean bacterial counts of water and carcasses is shown in Table 19. Figures 16 A and B and Figure 17 illustrate the effect of the normal system and the MRS on bacterial counts of water and carcasses.

Chlorination (TRT AB) and chlorination in conjunction with filtration (TRTs C and D) produced significant decreases in total aerobic and coliform counts of water and carcasses compared with the normal system (Table 19). However, a few exceptions were noted.

The plots illustrated in Figures 16A and B and Figure 17 show that the normal system of operation was less effective than the MRS in controlling bacteria in water and on carcasses. The main exception was TRT B (chlorination without filtration) at a water use rate of 10 m^3/d and 10 mg/l chlorine.

Although the multiple reuse system did not improve the chemical composition of scald water, a significant improvement in bacterial quality was observed. This improvement may be due to:

1- Continuous feeding at a fixed rate of the makeup water in the MRS compared to the intermittent feeding of water in the normal system, resulting in a greater dilution factor.

2- Only minor quantities of residual chlorine remained in the wash water reused in the scalder. However, chlorination of processing waters (fill and makeup), may have contributed to the improved bacterial quality of the scald water.

Effect of the MRS on Characteristics of Processing Water and Carcasses

As shown previously, there was no significant difference in bacterial quality of processing water or carcasses when chlorinated cooling water from the compressors (TRT B) was

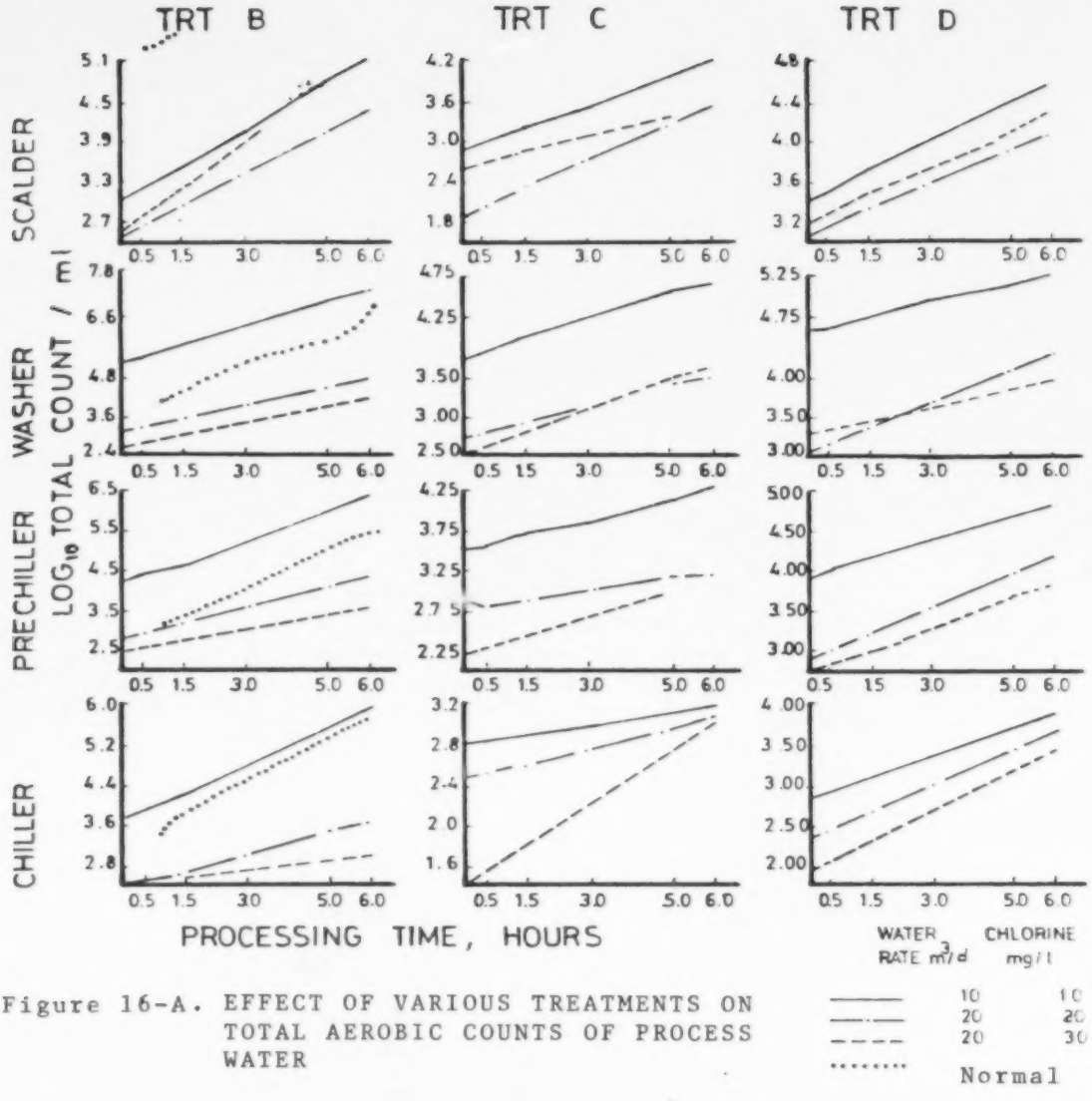


Figure 16-A. EFFECT OF VARIOUS TREATMENTS ON TOTAL AEROBIC COUNTS OF PROCESS WATER

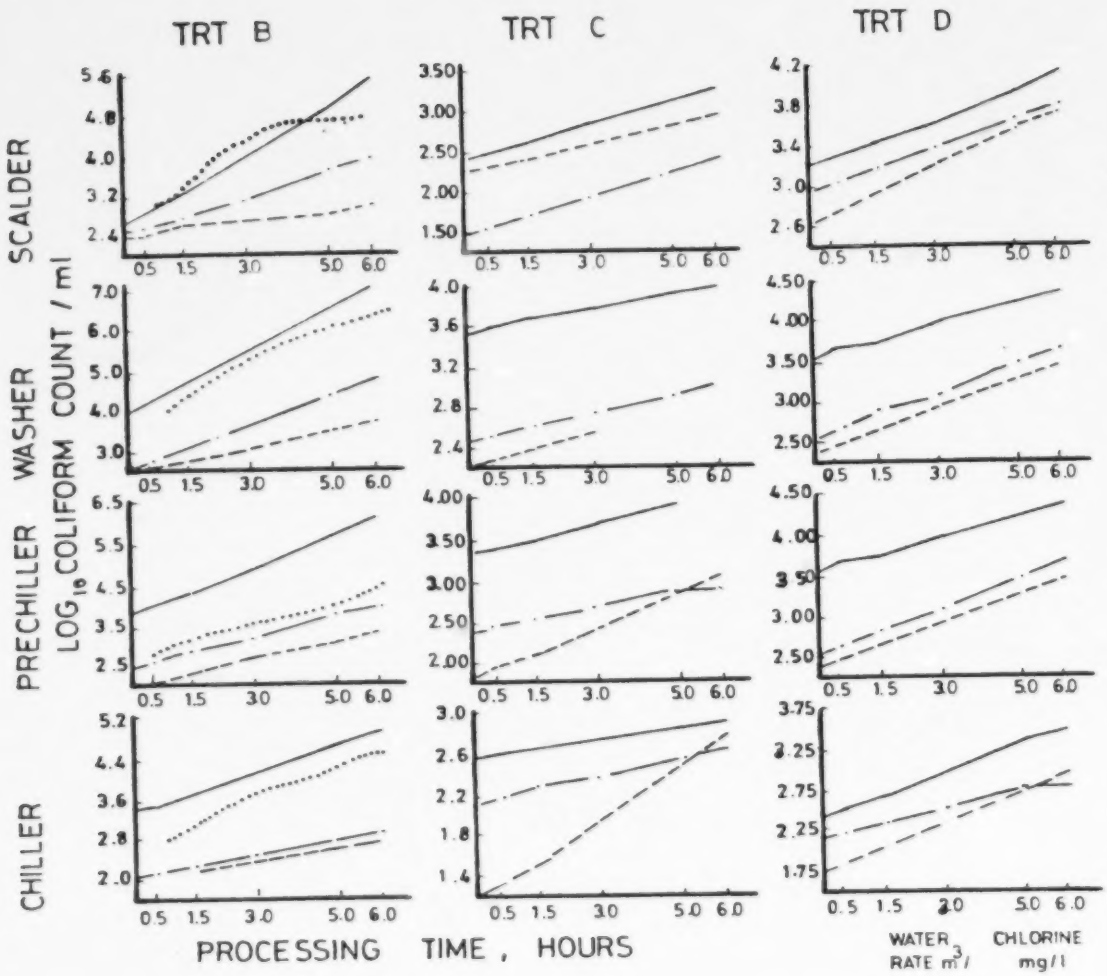
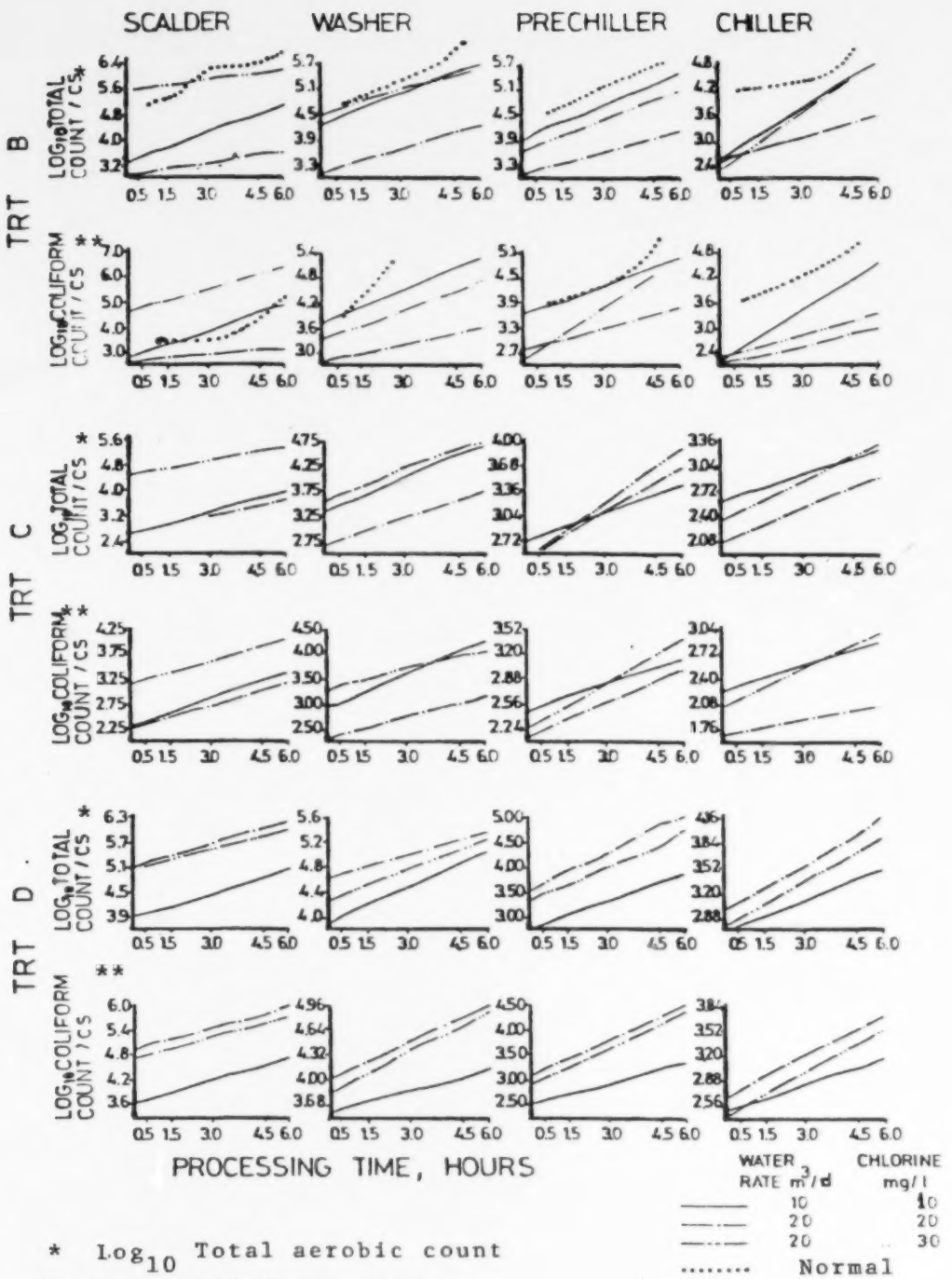


Figure 16-B. EFFECT OF VARIOUS TREATMENTS ON COLIFORM COUNTS OF PROCESS WATER



* Log_{10} Total aerobic count

** Log_{10} Coliform count

Figure 17. EFFECT OF VARIOUS TREATMENTS ON BACTERIAL COUNTS OF CARCESSES

Table 19. EFFECT OF NORMAL SYSTEM AND MULTIPLE WATER REUSE ON GEOMETRIC MEANS OF BACTERIAL COUNTS OF WATER AND CARCASSES

TRT	Water m^3/d	Cl_2 mg/l	n	$Log_{10}TC$	$Log_{10}TW$	$Log_{10}CC$	$Log_{10}CW$
SCALDER							
Normal			5	7.55 *	5.56 *	6.40 *	4.60 *
AB	10	10	2	4.88 S	4.61 S	3.74 S	3.88 S
	20	20	5	3.82 S	3.49 S	2.98 S	2.77 S
	20	30	2	5.60 S	3.45 S	5.01 S	2.51 S
C	10	10	5	3.18 S	3.30 S	2.80 S	2.77 S
	20	20	5	3.04 S	2.65 S	2.71 S	2.27 S
	20	30	4	4.89 S	2.98 S	3.55 S	2.54 S
D	10	10	3	4.34 S	3.85 S	4.02 S	3.51 S
	20	20	2	5.33 S	3.66 S	4.65 S	3.36 S
	20	30	2	5.47 S	3.49 S	5.14 S	3.16 S
PRECHILLER							
Normal			5,15[A]	5.41 *	5.11 *	4.39 *	3.04 *
AB	10	10	2	4.46 S	4.02 S	3.50 S	3.45 N
	20	20	5	4.05 S	3.30 S	3.37 S	2.71 S
	20	30	2	4.09 S	2.55 S	3.29 S	2.11 S
C	10	10	5	3.05 S	3.55 S	2.71 S	3.21 N
	20	20	5	3.00 S	2.94 S	2.49 S	2.60 S
	20	30	4	3.13 S	2.64 S	2.75 S	2.36 S
D	10	10	3	3.16 S	4.24 S	2.78 S	3.89 N
	20	20	2	4.10 S	3.40 S	3.56 S	2.96 N
	20	30	2	3.91 S	3.20 S	3.54 S	2.87 N

TRT	Water m^3/d	Cl_2 mg/l	n	$Log_{10}TC$	$Log_{10}TW$	$Log_{10}CC$	$Log_{10}CW$
WASHER							
				7.15 *	4.83 *	5.48 *	3.77 *
				4.28 S	4.61 N	3.55 S	3.76 N
				3.99 S	3.26 S	3.14 S	2.71 S
				4.72 S	2.99 S	3.80 S	2.58 S
				3.63 S	3.79 S	3.18 S	3.26 N
				3.00 S	3.03 S	2.67 S	2.69 S
				4.11 S	2.99 S	3.65 S	2.57 S
				4.36 S	4.78 N	3.75 S	4.47 N
				4.63 S	3.56 S	3.88 S	3.35 N
				4.70 S	3.55 S	4.28 S	3.26 N
CHILLER							
				4.76 *	3.83 *	3.98 *	2.96 *
				3.78 S	3.82 N	3.10 S	3.23 S
				3.78 S	2.45 S	3.07 S	2 03 S
				3.78 S	2.39 S	2.98 S	2.04 S
				2.85 S	2.87 S	2.45 S	2.69 N
				2.49 S	2.68 S	1.90 S	2.33 S
				2.78 S	2.12 S	2.49 S	1.90 S
				2.99 S	3.25 S	2.69 S	2.89 N
				3.44 S	2.87 S	3.07 S	2.48 S
				3.26 S	2.59 S	2.90 S	2.27 S

$Log_{10}TC$ = Log_{10} Total aerobic count / carcass.

$Log_{10}TW$ = Log_{10} Total aerobic count of water / ml.

Log_{10} CC = Log_{10} Coliform count / carcass .
Log_{10} CW = Log_{10} Coliform count of water /ml.

S = Significant at the 5% level

N = Not significant at the 5% level

n = Number of samples

A Water samples 15, Carcass samples 5

* = Control (Potable,non-chlorinated water.)

used for makeup in lieu of potable water (TRT A). Therefore, results from both treatments A and B were pooled and used in the following discussion as TRT AB, the control.

The effect of TRTs and OPCONs in the MRS on the quality of processing water and carcasses is summarized in Table 20. The following conclusions were drawn from Table 20:

1- Continuous filtration of the reused water in the wash tank and chiller (TRTs C and D) had a generally favorable effect on the chemical quality of the immersion waters. COD, BOD, TR and TSR were significantly lower in most instances for the filtered water than the nonfiltered water (TRT AB).

2- Levels of organic matter were appreciably lower in scald water whan wash water was filtered (TRT C) than when prechiller water was filtered (TRT D), probably because water from the washer entered the scalder directly whereas water from the prechiller was reused in the washer before reaching the scalder.

3- Filtration of the wash water (TRT C) improved its quality. Significant reductions of TSR, O&G, TR, BOD, and COD were achieved. TRT D which involved filtration of the preceding process (prechiller) was significantly less effective in lowering pollutants in the wash water, especially O&G and TSR from the wash water. This result is also seen in Figure 15 B.

4- Filtration of the prechiller water (TRT D) significantly improved the quality of this water (Figure 15 C). TRT C produced no significant improvement in the quality of the prechiller water;COD, BOD, O&G and TSR were not significantly different for TRTs AB and C in the prechiller water.

5- Significant reductions of the COD and TR of the chiller water were achieved while applying TRT D. This may be attributed to the improved quality of the prechiller water (TRT D), the most immediate step prior to carcass entry into the chiller.

6- The mean concentration of pollutants generally decreased by increasing the water rate from 10 to 20 m^3/d and chlorine dosages from 10 to 30 mg/l (OPCONS 2 and 3). However, some exceptions were noted.

7- Filtration of wash and prechiller waters (TRTs C and D) produced no significant differences in total aerobic and coliform counts in water from the washer and chillers compared to the nonfiltered water

Table 20 EFFECT OF TREATMENT AND OPERATING CONDITIONS IN THE MULTIPLE REUSE SYSTEM ON CHARACTERISTICS OF PROCESS WATER AND CARCASSES

Source	n	COD (mean mg/l)	BOD (mean mg/l)	TR (mean mg/l)	O&G (mean mg/l)	TSR (mean mg/l)	Mean count/ml $Log_{10}TW$	Mean count/ml $Log_{10}CW$	Mean count/carcass $Log_{10}TC$	Mean count/carcass $Log_{10}CC$
SCALDER										
TRT AB	8	2303 *	1600 *	2775 *	101 *	1182 *	3.85 *	3.05 *	4.77 *	3.91 *
C	12	1623 S	1153 S	1899 S	93 N	784 S	2.98 S	2.53 S	3.70 S	3.02 S
D	12	1604 S	1482 N	2280 S	104 N	762 S	3.67 N	3.34 N	5.05 N	4.60 S
OPCON 1	8	2198 *	1870 *	2731 *	107 *	962 *	3.92 *	3.39 *	4.13 *	3.51 *
2	15	1594 S	1142 S	2060 S	100 N	983 N	3.26 S	2.80 S	4.06 N	3.44 N
3	7	1738 S	1222 S	2163 S	90 N	783 S	3.31 S	2.73 S	5.31 S	4.56 S
WASHER										
TRT AB	8	832 *	570 *	2013 *	149 *	523 *	3.61 *	3.01 *	4.33 *	3.46 *
C	12	419 S	344 S	1143 S	45 S	165 S	3.26 N	2.84 N	3.58 S	3.16 N
D	12	491 S	410 S	820 S	108 S	427 N	3.97 N	3.70 N	4.57 N	3.97 N
OPCON 1	8	640 *	532 *	1419 *	115 *	313 *	4.39 *	3.83 *	4.09 *	3.46 *
2	15	621 N	484 N	1353 N	100 N	359 N	3.28 S	2.91 S	3.87 N	3.22 N
3	7	481 S	309 S	1203 N	86 N	350 N	3.18 S	2.80 S	4.51 N	3.91 N
PRECHILLER										
TRT AB	8	413 *	271 *	1024 *	100 *	427 *	3.29 *	2.76 *	4.20 *	3.38 *
C	12	379 N	303 N	794 S	107 N	386 N	3.04 N	2.72 N	3.06 S	2.65 S
D	12	174 S	144 S	544 S	51 S	128 S	3.61 N	3.24 N	3.73 S	3.29 N
OPCON 1	8	379 *	305 *	955 *	95 *	426 *	3.94 *	3.51 *	3.56 *	2.99 *
2	15	306 S	227 S	788 S	99 N	314 S	3.21 S	2.76 S	3.71 N	3.13 N
3	7	281 S	188 S	618 S	65 S	233 S	2.79 S	2.44 S	3.71 N	3.19 N
CHILLER										
TRT AB	8	368 *	222 *	720 *	86 *	229 *	2.89 *	2.31 *	3.78 *	3.04 *
C	12	312 S	244 N	736 N	112 N	295 N	2.56 N	2.54 N	2.71 S	2.28 S
D	12	216 S	181 N	549 S	98 N	256 N	2.90 N	2.43 N	3.23 N	2.89 N
OPCON 1	8	377 *	276 *	755 *	114 *	370 *	3.31 *	2.93 *	3.20 *	2.75 *
2	15	278 S	213 S	660 S	110 N	255 S	2.61 S	2.28 S	3.24 N	2.68 N
3	7	241 S	158 S	569 S	70 S	189 S	2.36 S	2.07 S	3.27 N	2.78 N

$Log_{10}TW$ = Log_{10} Total count of water/ml
$Log_{10}CW$ = Log_{10} Coliform count of water/ml
$Log_{10}TC$ = Log_{10} Total count /carcass
$Log_{10}CC$ = Log_{10} Coliform count/carcass
Refer to pp 57 for explansion of TRTs and OPCONs

S= Significant at the 5% level
N= Not singificant at the 5% level
*= Control
Data of TRTs pooled for OPCON 1, 2 and 3
Data of OPCONs pooled for TRTs AB, C and D

(TRT AB). However, TRT C (filtration of wash water) significantly reduced bacterial levels in scald water (filtered wash water was used for makeup in the scalder). These results indicate that filtration alone is not effective in reducing bacterial levels in processing water in a multiple reuse system.

8- Even though filtration did not improve the microbiological quality of processing water in all the immersion tanks, Table 20 and Figure 17 show that filtration of wash water (TRT C) resulted in significant bacterial reductions on carcasses from most of the immersion tanks. Filtration and chlorination of wash water (TRT C) prior to reuse in the scalder improved the quality of the scald water (Table 20). This seems to have reduced the level of cross-contamination of carcasses resulting in a microbiologically improved final product from the chiller.

It was, therefore, concluded that filtration and chlorination of wash water (TRT C) constituted the best approach in this multiple reuse system.

The rate of accumulation of organic pollutants in the immersion tanks was generally larger for TRTs A and B than for TRTs C and D. In considering the filtration effect, it is concluded that operating the MRS would lead to attaining steady-state conditions in relatively shorter time, in addition to the overall less pollutants concentrations in the immersion tank with TRTs C and D compared to TRTs A and B.

The progressive accumulation of bacteria in the water and carcasses during a 6 hour processing period are illustrated in Figures 18 and 19. The Figures indicate that filtration (TRTs C and D) helps achieving steady-state conditions in relatively shorter time compared to the nonfiltration scheme (TRT AB), and that TRT C lowered bacterial counts more than TRT D.

Analysis of variance was used with grouping of variables: TRTs, OPCONs, hours,dates and some selected interactions of these variables. As seen in the ANOVA reported in Table 21 almost all variables have significant effects on the chemical parameters while most interactions were not significant.

Chlorine level, water makeup rate and their interaction were used as independent variables for data from the fifth hour after startup. The resulting ANOVA for the separate treatments is shown in Table 22. This ANOVA identifies several facts:

1- Chlorine level had a significant effect on bacterial

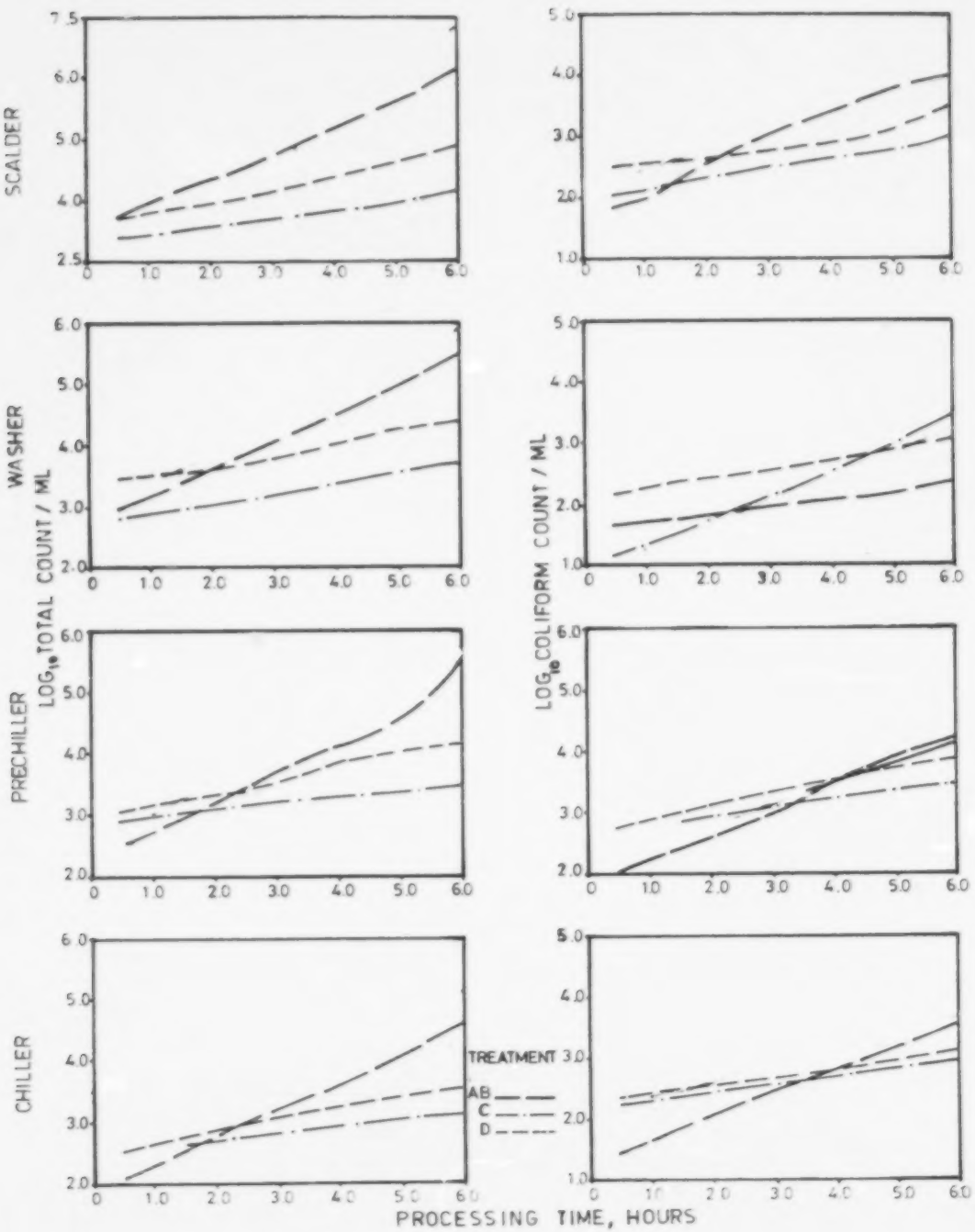


Figure 18. EFFECT OF TREATMENTS AB, C and D ON BACTERIAL COUNTS OF PROCESS WATER

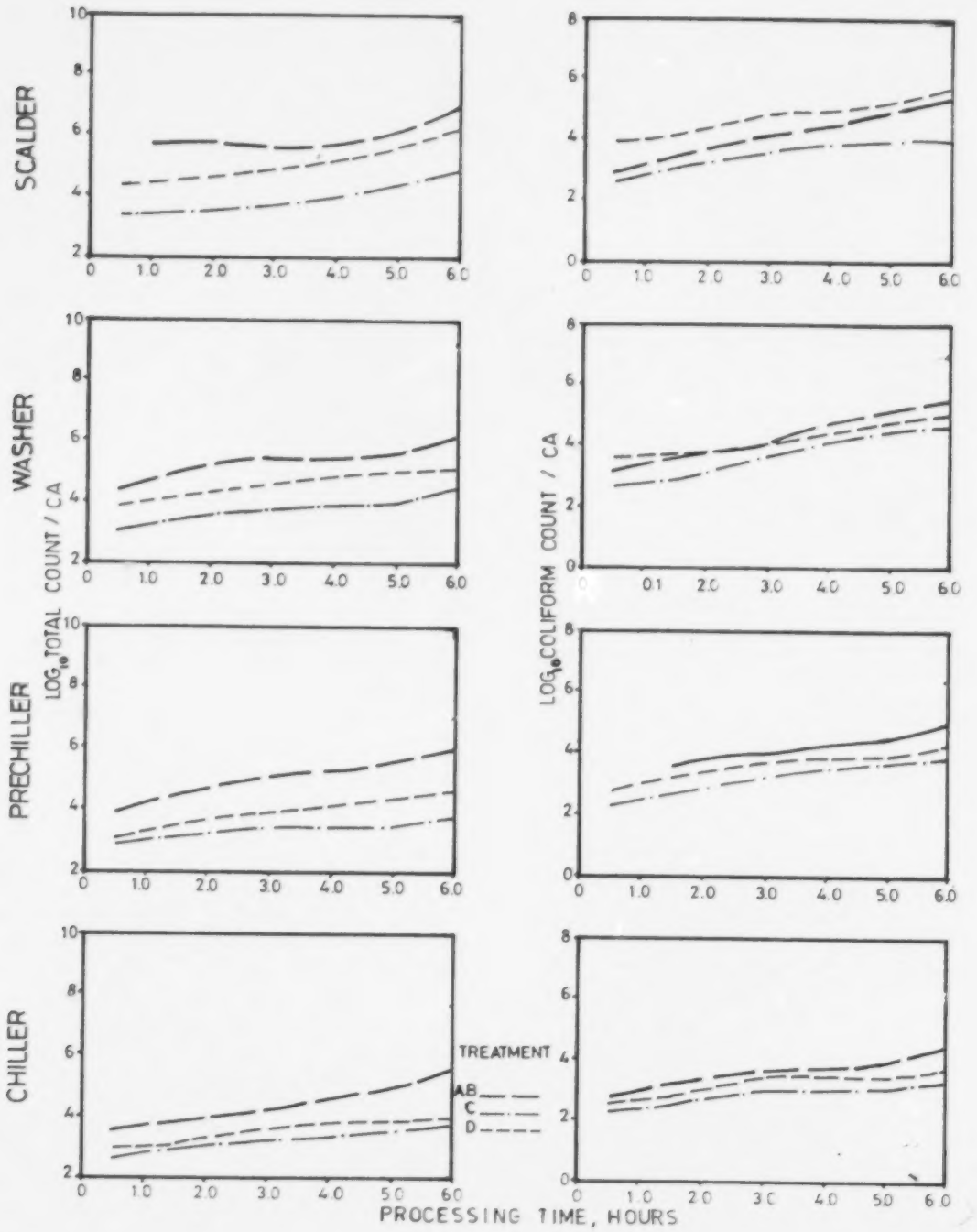


Figure 19. EFFECT OF TREATMENTS AB, C and D ON BACTERIAL COUNTS OF CARCASSES

Table 21. EFFECT OF TREATMENT, OPERATING CONDITIONS AND PROCESSING TIME ON CHEMICAL CHARACTERISTICS OF PROCESS WATER

SOURCE	COD				BOD				TR				TSR				DR			GREASE			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	1	2	3	4
O	S	S	N	S	S	N	S	S	S	S	S	N	N	N	S	N	S	S	S	S	S	N	N
H	S	S	N	S	S	S	S	S	S	S	S	S	S	S	N	S	S	S	S	S	N	N	S
TRT (T)	S	S	S	S	N	N	S	S	S	S	S	N	S	N	N	S	S	S	S	S	S	S	N
T*O	S	N	N	N	S	N	N	N	S	N	S	N	N	S	N	N	S	N	S	S	S	N	N
DATE (T*O)	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	N	S	S	S
H*H	S	S	S	S	S	S	S	S	N	S	S	N	S	N	S	S	S	N	N	S	N	S	N
H*T	S	S	N	S	N	N	N	S	N	N	S	N	N	S	S	S	N	S	N	S	S	N	N
H*T	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	S	S	N	N
H*O*T	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	S	S	N	N	N
H*H*T	S	S	N	S	N	S	N	S	N	N	S	N	S	N	S	S	S	N	S	S	S	S	N
H*H*O	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	S	S	S	N	N	N
H*H*O*T	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	S	S	N	N	N

S = Significant at the 5% level

N = Not significant at the 5% level

TRT = Treatment A VS B VS C VS D.

O = Operating Conditions

I (Cl_2 = 10 mg/l, makeup = 10 m^3/d)

II (Cl_2 = 20 mg/l, makeup = 20 m^3/d)

III (Cl_2 = 30 mg/l, makeup = 20 m^3/d)

H = Hours 1, 2, 3, 4, 5 and 6

1 = Scalder

2 = Washer

3 = Prechiller

4 = Chiller

Table 22 . ANOVA FOR THE EFFECT OF CHLORINE LEVELS AND WATER MAKEUP RATES ON BACTERIAL COUNTS OF CARCASSES AND WATER FIVE HOURS AFTER START-UP

TRT=AB

SOURCE	SCALDER				WASHER				PRECHILLER				CHILLER			
	TW	CW	TC	CC	TW	CW	TC	CC	TW	CW	TC	CC	TW	CW	TC	CC
DOSE	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
DOSE*DOSE	S	S	S	S	S	N	S	S	N	N	S	S	S	S	S	S
WATER RATE	N	S	N	N	N	N	N	N	N	N	S	N	N	N	N	S
DOSE*RATE	N	N	N	N	N	S	N	N	S	S	N	N	N	N	N	N

TRT=C

DOSE	S	S	S	S	S	S	N	S	S	S	S	S	S	S	S	S
DOSE*DOSE	S	S	S	S	N	N	S	S	N	S	S	S	S	S	S	S
WATER RATE	N	S	N	N	S	S	N	N	S	S	S	S	N	N	N	S
DOSE*RATE	N	N	N	N	S	S	N	N	N	S	S	N	N	N	N	N

TRT=D

DOSE	S	N	N	N	S	S	S	N	S	S	N	N	S	S	S	N
DOSE*DOSE	S	N	N	N	S	S	S	N	S	S	N	N	N	N	N	S
WATER RATE	S	N	S	S	S	S	S	S	S	S	S	S	S	S	S	S
DOSE*RATE	S	N	N	N	S	S	S	N	N	N	N	N	N	N	N	N

TW=Log_{10}Total aerobic count of water/ml
CW=Log_{10}Coliform count in water/ml
TC=Log_{10}Total aerobic count of carcass
CC=Log_{10}Coliform count of carcass
S = Significant at the 5% level
N = Not significant at the 5% level
Cl_2 Dose = 10, 20 and 30 mg/l

Water rate TRT AB = 10, 20, 30, and 40 m^3/d
TRT C and D = 10 and 20 m^3/d

counts in TRTs AB and C.
The effect on TRT D was less significant.

2- Increasing the water makeup rate in TRT AB had no significant effect on bacterial counts five hours after start-up. The increase of water rate from 10 to 40 m^3/d was apparently not sufficient to reduce bacterial buildup while using nonfiltered water in the MRS.

3- Increasing the water makeup rate in TRTs C and D (Filtered water) from 10 to 20 m^3/d had a significant effect on bacterial counts of wash and chilling waters (except for the chiller water counts in TRT C).

4- In general there is no significant interaction between chlorine dose and makeup rate, though significant interactions were found in a few cases.

Response Surface Contours of Bacterial Counts in Relation to Water Makeup Rate and Processing Time Using Various Levels of Chlorination

The response surface analysis for bacterial counts in water at various water makeup rates and processing times is shown in Figure 20 at three levels of chlorination:

i- No chlorination

ii- Chlorine dose 10-20 mg/L. The data in this case was pooled for all treatments;

iii- Chlorine dose 30-50 mg/L. The data was that of TRT AB only.

For the most part, the increase in makeup rate produced parallel improvement in bacterial counts while using chlorinated water. However, as time passed, a reverse tendency for quality deterioration at rates higher than 20-25 m^3/d was noted. This is attributed to the increased chilling temperature at higher makeup rates which was presumably associated with accelerated bacterial growth rates. The response surfaces clearly demonstrate the favorable effect of increasing the chloride dose on the water bacterial quality In almost all cases, the use of chlorine dose of 10-20 mg/L produced an appreciable reduction in the magnitude and rate of bacterial accumulation. The water makeup rate was optimum at 20 m^3/d while using chlorinated water. This was distinctly shown in the prechiller and chiller waters in Figures 20-C and 20-D respectively, as the contours of relatively low bacterial counts were dominating at makeup rate of 20 m^3/d and chlorine dose of 10 - 20 mg/L.

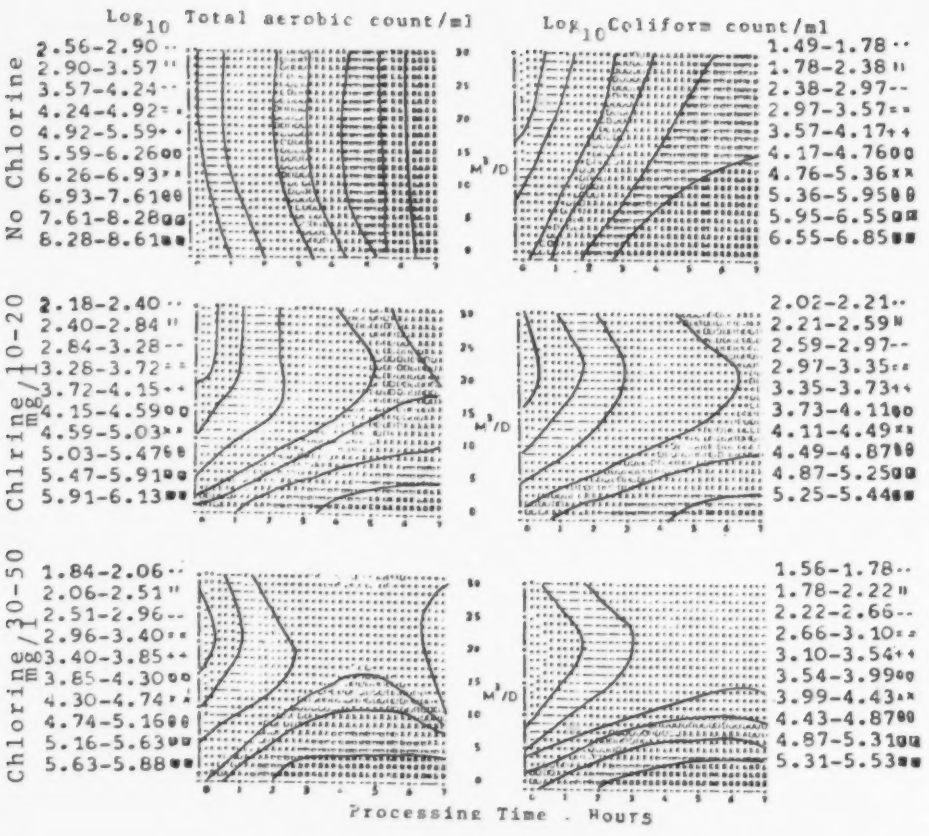


Figure 20-A RELATIONSHIP BETWEEN BACTERIAL COUNTS OF SCALDER WATER, PROCESSING TIME, AND WATER MAKEUP RATE
[Data pooled for all treatments]

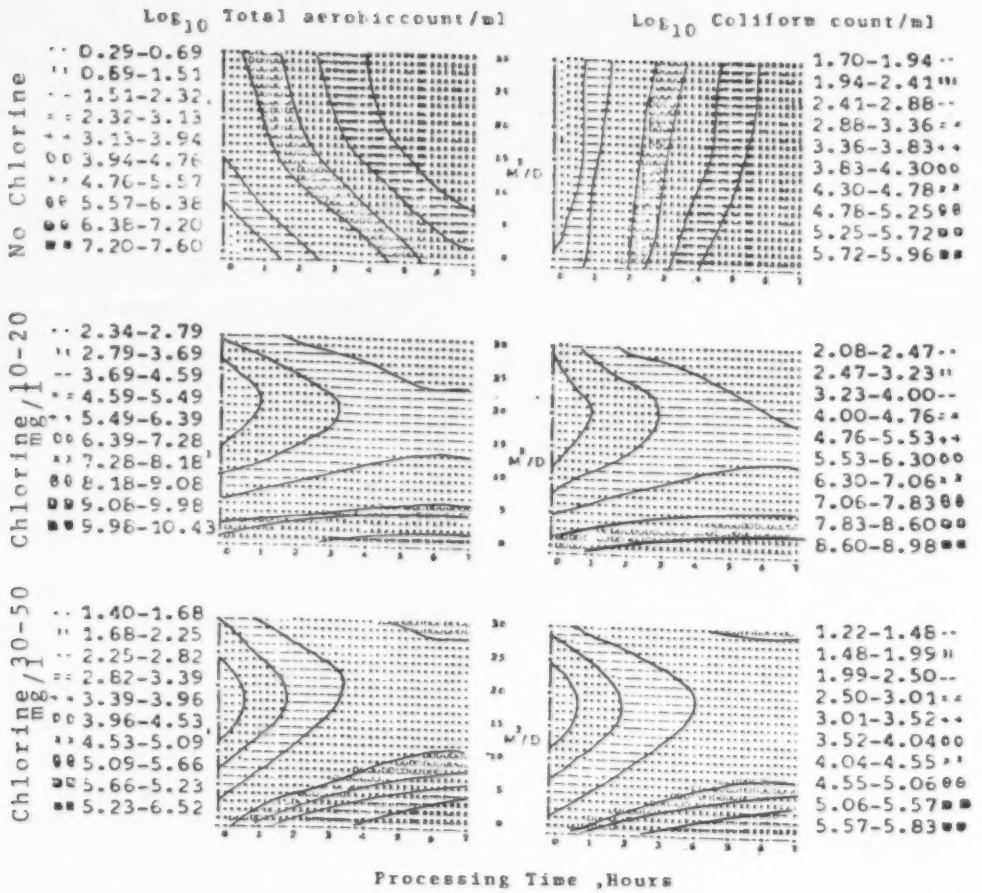


Figure 20-B RELATIONSHIP BETWEEN BACTERIAL COUNTS OF WASH WATER, PROCESSING TIME AND WATER MAKEUP RATE
[Data pooled for all treatments]

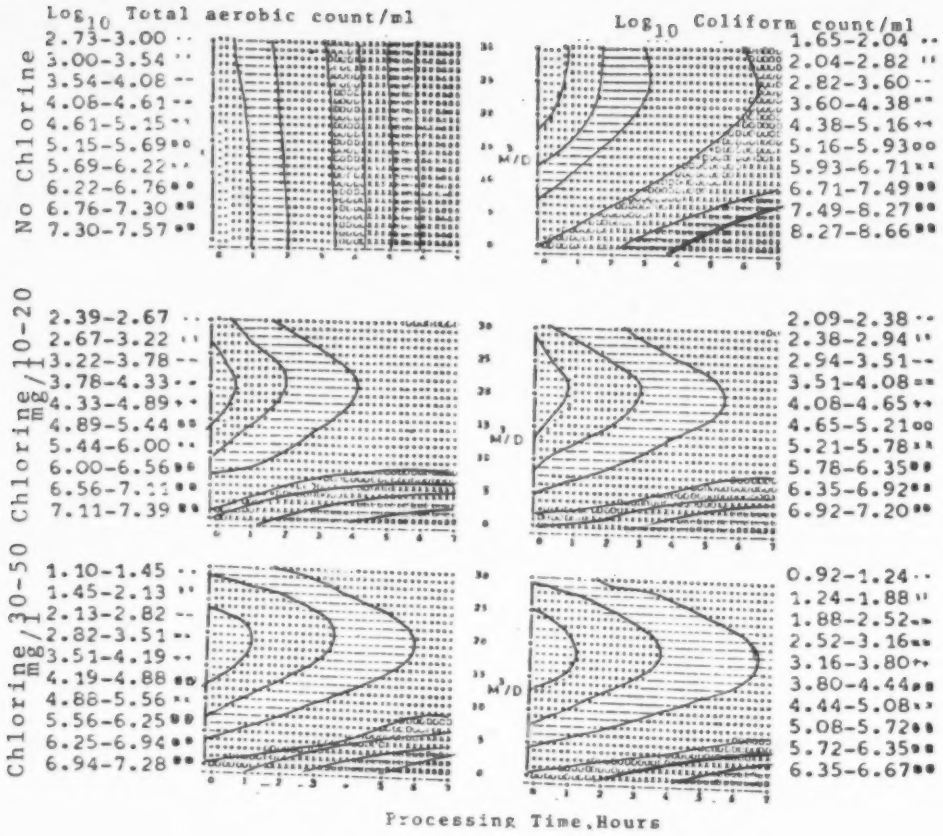


Figure 20-C RELATIONSHIP BETWEEN BACTERILA COUNTS OF PRECHILLER WATER, PROCESSING TIME AND WATER MAKEUP RATE
[Data pooled for all treatments]

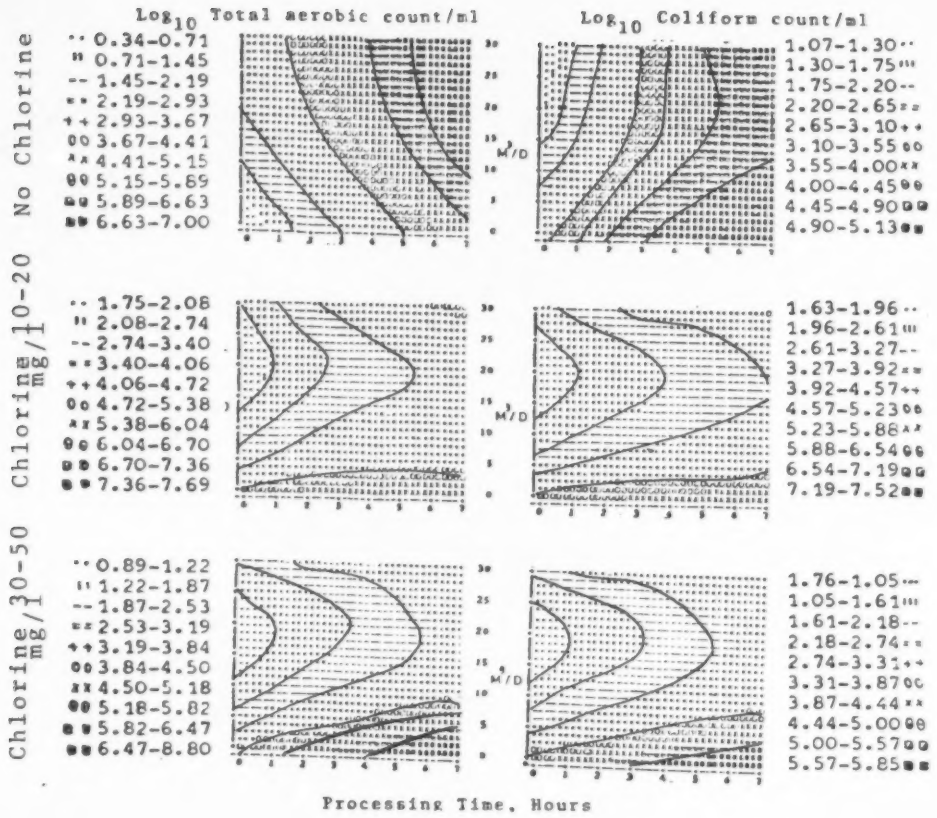


Figure 20-D RELEATIONSHIP BETWEEN BACTERIAL COUNTS OF CHILLER WATER, PROCESSING TIME AND WATER MAKEUP RATE
[Data pooled for all treatments]

However, further increase of chlorine dose from 30 to 50 mg/l was not generally accompanied by parallel improvement in the bacterial quality. In case of chlorinated water, both total and coliform counts responded in the same manner to the makeup rate and chlorine dose. This is demonstrated by the similarity of their response surfaces at various operating conditions.

The effect of makeup rate and processing time on the carcasses bacterial quality is shown in Figure 21. The most striking fact is the less visible effect of increased makeup rate of the chlorinated water on the bacterial quality of carcasses. This result strongly indicates that proper operations; i.e., standard chilling temperatures, water chlorination and renovation are reliable alternatives to increased makeup rate for keeping acceptable bacterial quality throughout the 7-hour processing period.

The responses shown in Figure 21 are based on small numbers of samples. Analyses of a larger number of samples could affect these results. In any event, Figure 21 indicates that bacterial counts of carcasses were a function of processing time rather than water makeup rate. The results show little to no improvement of the carcass bacterial quality by increasing the chlorine dose to levels higher than 20 mg/l.

COMPARISON OF CHLORINATED AND NON-CHLORINATED WATER IN THE MULTIPLE REUSE SYSTEM (PHASE VII)

Phase VII involved testing TRTs C and D without chlorination. Bacterial counts of the carcasses and water in the chlorinated system (Phase V) were generally significantly less than those of phase VII as shown in Table 23. The differences of the bacterial counts of phases VI and VII were not significant. On the other hand, the results of Table 23 show that the pollutants in water using phase VII were not significantly different from those of phase V (TRT C) and phase VI (TRT D). However, some exceptions were noted.

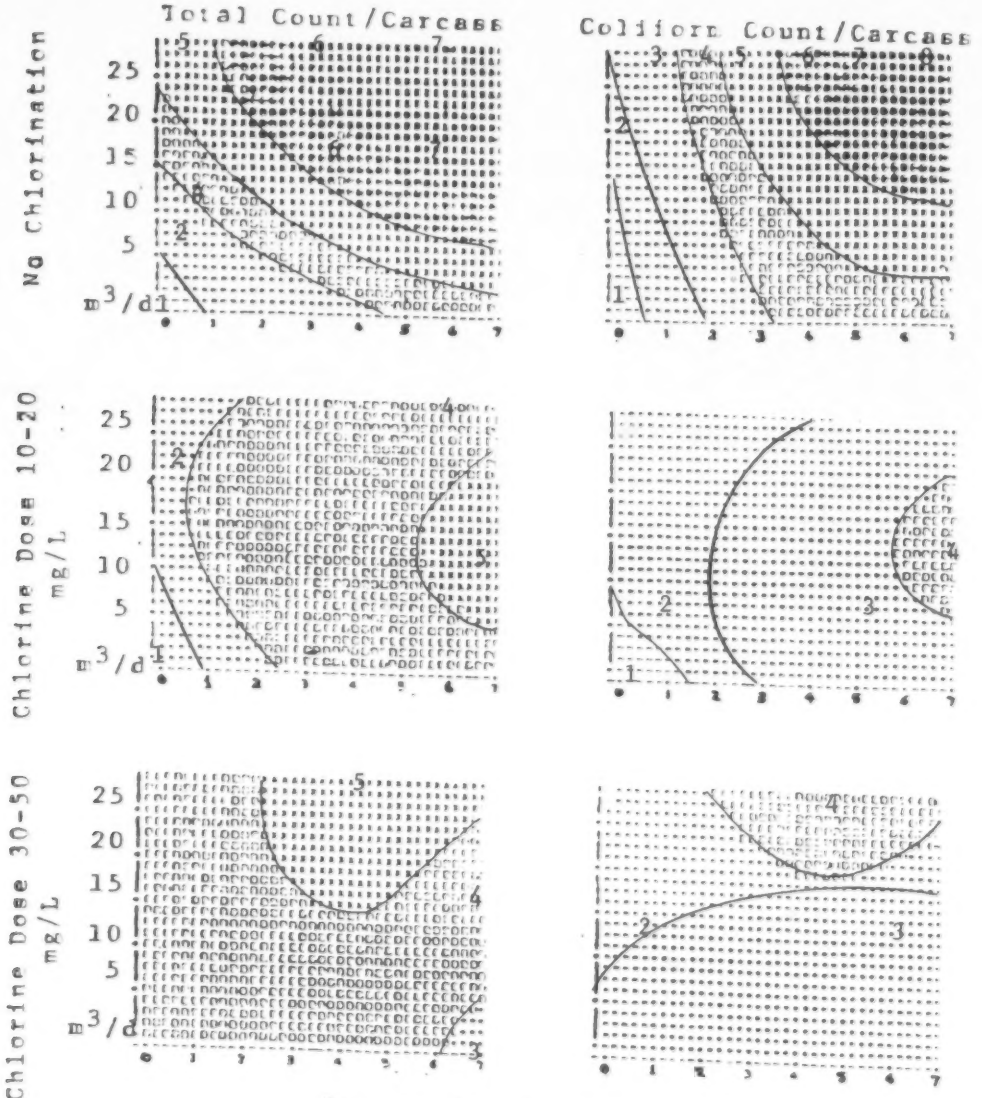
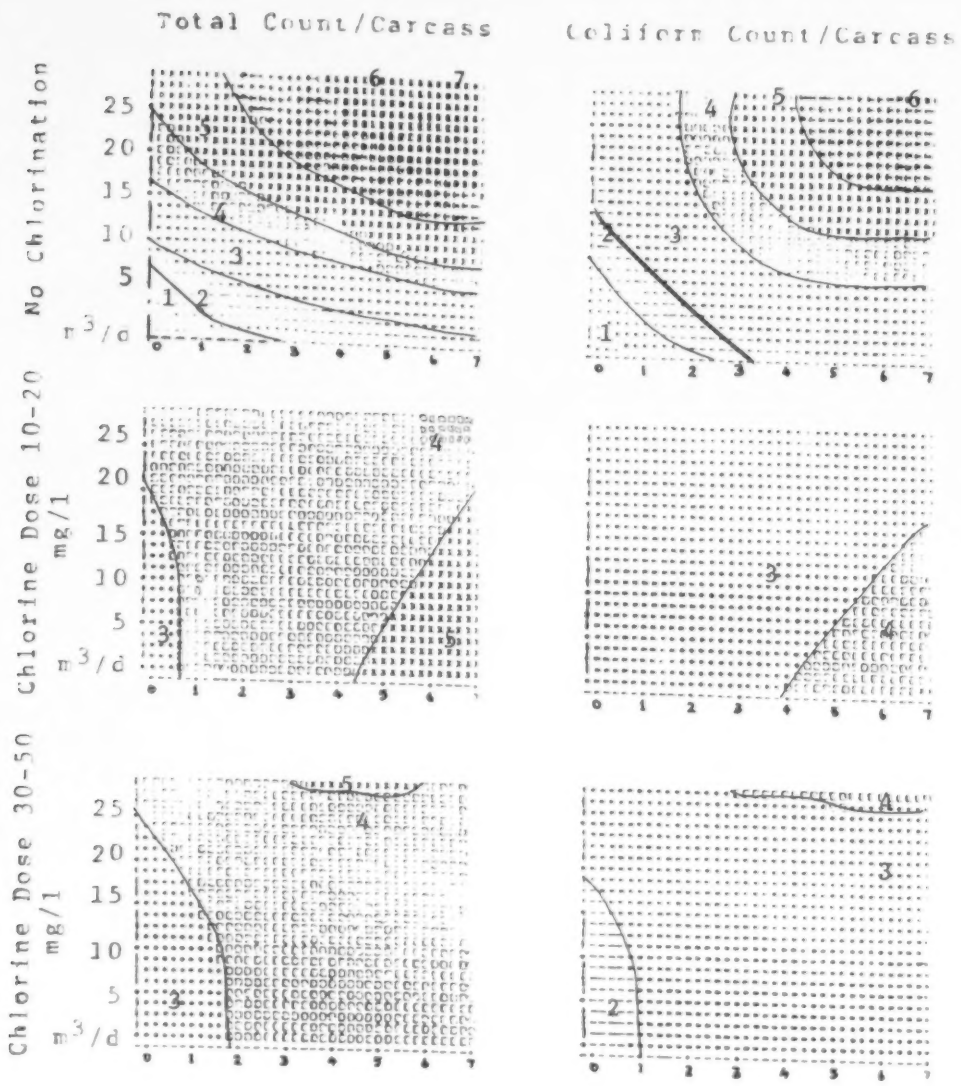
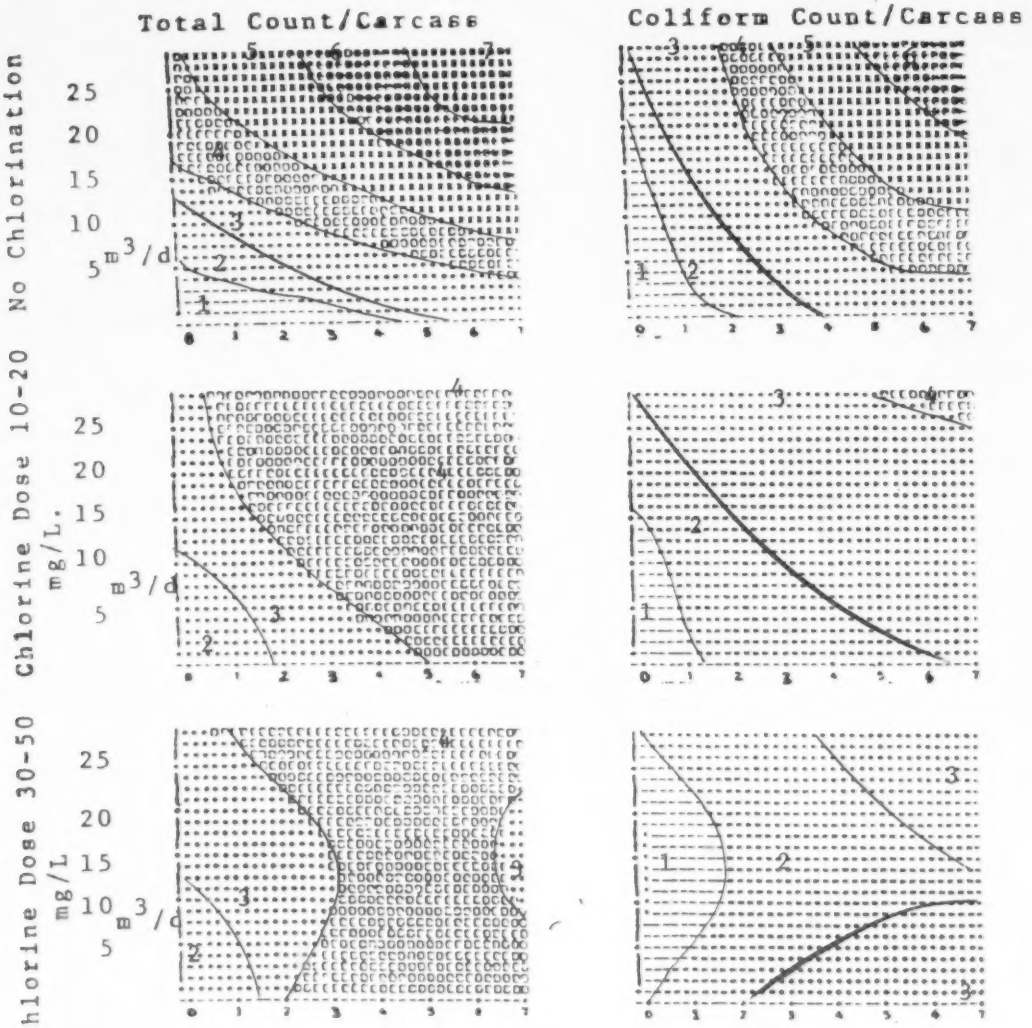


Figure 21-A RELATIONSHIP BETWEEN CARCASS BACTERIAL COUNTS IN THE SCALDER PROCESSING TIME AND MAKEUP RATE
(DATA POOLED FOR ALL TREATMENTS)



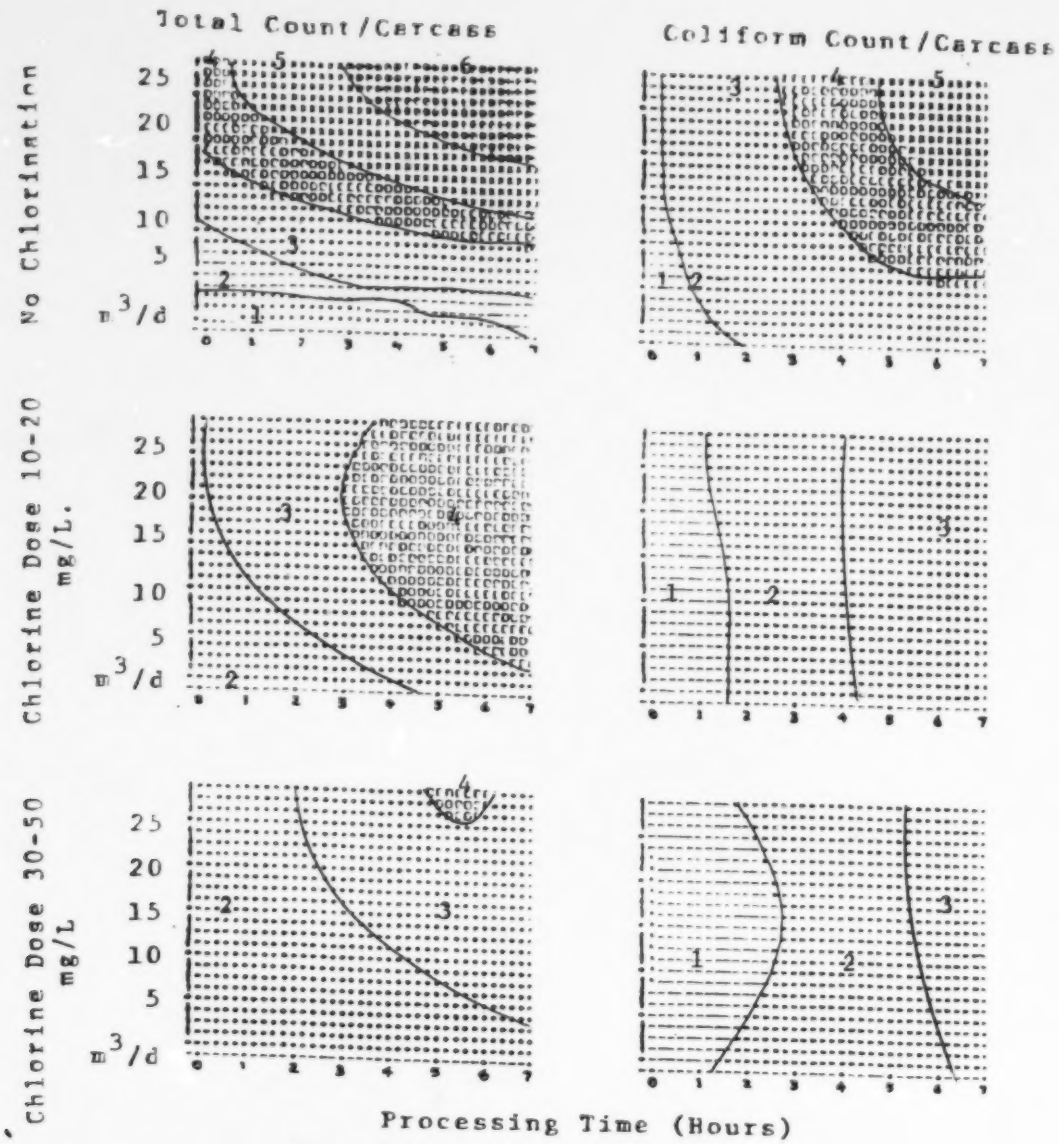
	Log_{10} T. Aerobic Count			Log_{10} Coliform Count		
1	0.71	-	2.10	1	1.71	- 2.57
2	2.10	-	3.49	2	2.57	- 3.33
3	3.49	-	4.87	3	3.33	- 4.13
4	4.87	-	6.26	4	4.13	- 4.49
5	6.26	-	7.65	5	4.49	- 5.75
6	7.65	-	9.02	6	5.75	- 6.60
7	9.02	-	9.73	7	6.60	- 7.37
				8	7.37	- 7.77

Figure 21-B RELATIONSHIP BETWEEN CARCASS BACTERIAL COUNTS IN THE WASHER PROCESSING TIME AND MAKEUP RATE
(DATA POOLED FOR ALL TREATMENTS)



	Log_{10}T. Aerobic Count		Log_{10} Coliform Count
1	0.71 – 2.10	1	1.71 – 2.52
2	2.10 – 3.49	2	2.52 – 3.33
3	3.49 – 4.87	3	3.33 – 4.13
4	4.87 – 6.26	4	4.13 – 4.49
5	6.26 – 7.65	5	4.49 – 5.75
6	7.65 – 9.04	6	5.75 – 6.56
7	9.04 – 9.73	7	6.56 – 7.37

Figure 21-C RELATIONSHIP BETWEEN CARCASS BACTERIAL COUNTS. PROCESSING TIME AND MAKEUP RATE IN THE PRECHILLER (DATA POOLED FOR ALL TREATMENTS)



	Log_{10} T. Aerobic Count		
1	0.71	-	2.10
2	2.10	-	3.49
3	3.49	-	4.87
4	4.87	-	6.26
5	6.26	-	7.65
6	7.65	-	9.04
7	9.04	-	9.73

	Log_{10} Coliform Count		
1	1.71	-	2.52
2	2.52	-	3.33
3	3.33	-	4.13
4	4.13	-	4.49
5	4.49	-	5.75
6	5.75	-	6.56
7	6.56	-	7.37
8	7.37		7.77

Figure 21-D RELATIONSHIP BETWEEN CARCASS BACTERIAL COUNTS IN THE CHILLER. PROCESSING TIME AND MAKEUP RATE
(DATA POOLED FOR ALL TREATMENTS)

Table 23 EFFECT OF CHLORINATION ON THE QUALITY OF PROCESS WATER AND CARCASSES

	SCALDER					WASHER				
	TRT C			TRT D		TRT C			TRT D	
	(Phase VII)	(Phase V)		(Phase VII)	(Phase VI)	(Phase VII)	(Phase V)		(Phase VII)	(Phase VI)
Chlorine dose, mg/l	0	20		0	20	0	20		0	20
Water rate, m^3/d	20	20		20	20	20	20		20	20
Number of Samples	12	20		12	20	12	20		12	20
Parameters										
COD, mg/l	1083	1347	S	1078	960 N	418	430	N	611	519 N
BOD, mg/l	886	883	N	929	850 N	366	365	N	476	448 N
TR, mg/l	1720	1624	N	1704	1673 N	783	793	N	1244	1122 N
DR, mg/l	1006	845	N	1002	968 N	591	611	N	735	709 N
O&G, mg/l	121	102	N	130	117 N	57	46	N	129	90 N
$Log_{10}TW$	4.46	2.64	S	3.04	3.66 S	3.07	3.03	N	3.55	3.56 N
$Log_{10}CW$	3.63	2.24	S	3.24	3.33 N	2.94	2.69	S	3.46	3.35 N
$Log_{10}TC$	3.81	3.04	S	4.90	5.35 N	3.47	3.01	S	4.05	4.67 S
$Log_{10}CC$	3.34	2.71	S	4.09	4.69 S	2.95	2.66	S	3.59	3.32 N

	PRECHILLER					CHILLER				
	TRT C			TRT D		TRT C			TRT D	
	(Phase VII)	(Phase V)		(Phase VII)	(Phase VI)	(Phase VII)	(Phase V)		(Phase VII)	(Phase VI)
Chlorine dose, mg/l	0	20		0	20	0	20		0	20
Water rate, m^3/d	20	20		20	20	20	20		20	20
Number of Samples	12	20		12	20	12	20		12	20
Paramaters										
COD, mg/l	357	347	N	78	140 S	241	291	N	104	177 S
BOD, mg/l	293	274	N	69	118 N	211	240	N	86	163 S
TR, mg/l	598	753	S	415	552 S	619	736	N	349	501 S
DR, mg/l	379	438	S	333	408 S	392	450	S	309	224 S
O&G mg/l	127	144	N	24	40 N	86	142	S	49	90 S
$Log_{10}TW$	2.89	2.95	N	3.32	3.41 N	2.93	2.69	S	2.84	2.87 N
$Log_{10}CW$	2.48	2.60	N	3.08	2.97 N	2.58	2.33	S	2.60	2.48 N
$Log_{10}TC$	3.26	3.00	S	3.81	4.10 N	3.15	2.45	S	3.44	3.45 N
$Log_{10}CC$	2.79	2.49	S	3.41	3.57 N	2.81	1.88	S	2.98	3.07 N

$Log_{10}TC$ = Log_{10} Total aerobic ount/carcass
$Log_{10}TW$ = Log_{10} Total aerobic count/carcass
$Log_{10}CC$ = Log_{10} Coliform count/carcass
$Log_{10}CW$ = Log_{10} Coliform countof water /ml

N = Not significant at the 5% level

S = Significant at the 5% level (Comparison between phase VII and phase V or phase VI)

PESTICIDES IN THE MULTIPLE WATER REUSE SYSTEM

Types and concentrations of pesticides were determined in the fresh water supply, in the chlorinated process water, in the reused water in the immersion tanks and in the filtered recycled water in the washer.

A study by Andelman and Clise[10], indicated the presence of Heptachlor, Endrin and Lindane in the carcass and chiller water at Sterling Poultry Processing Plant in Maryland, USA. A study by El-Sebae and Abu-Elamayem [19], indicated that Lindane;∝-BHC; Heptachlor;Heptachlor expoxide;P, P'-DDE and o, p' DDT were detected in raw and treated water supplies of Alexandria.

The results of analysis of water supply at APPP are shown in Table 24. The results indicated the presence of Lindane, ∝-BHC, Heptachlor, Hetachlor expoxide, O, P'-DDE, P, P'-DDE, O, P'-DDT, and P, P'-DDT. Lindane and ∝-BHC were detected in most of the analysed samples. On the other hand, Heptachlor, and Hetachlor expoxide were detected once during the testing period. The major metabolites of DDT, namely O, P'-DDE and P, P'-DDE were detected in several samples during the period of analysis while DDT and its isomer O, P'-DDT were only detected once in the analysed samples.

Effect of water chlorination at APPP on pesticides' content is shown in Table 25. The results indicated that there is no significant difference among concentrations of the detected pesticides in the chlorinated and non-chlorinated waters.

The results of total DDT and ∝-BHC compounds in the reused water shown in Table 25 indicate appreciable successive derease of total DDT and ∝-BHC compounds by reuse from the final chiller to the prechiller and the washer. This could be attributed to the adsorption of pesticides on residues in the tanks and onto the carcass tissue. The decrease in the pesticides contents was related to the successive decrease of the residues of the process water in the final chiller, prechiller and washer.

In the scalder a significant increase in pesticides was detected. It is postulated that the pesticides attached to the chicken feather contributed to the pesticidal pollution of the scalder water, while adsorption of pesticides on particulate matter apparently plays a minor role in the scalder.

The results of Table 26 indicate moderate removal of pesticides by filtration.

Filtration is basically effective for the removal of suspended residues from the process water. However, soluble pesticides and other organic constituents are partially removed by adsorption on the filter cake during filtration process.

Table 24. PESTICIDES IN APPP WATER SUPPLY
(ug/l)

A. NON-CHLORINATED WATER

MONTH 1978	∝-BHC	LINDANE	HEPTACHLOR EPOXIDE	HEPTACHLOR	O,P'-DDE	P,P'-DDE	O,P'-DDT	P,P'-DDT
FEB.	0.80	3.00	ND	ND	ND	ND	ND	ND
MARCH	ND	4.00	ND	ND	5.50	1.50	ND	ND
MAY	1.66	4.60	ND	ND	3.10	6.20	ND	ND
JULY	0.10	0.29	0.12	ND	0.47	ND	0.95	ND
AUG	0.85	2.20	ND	0.53	3.08	ND	ND	ND
NOV	1.29	0.43	ND	ND	ND	1.50	ND	1.50
DEC	ND	0.90	ND	ND	ND	1.20	ND	ND
MEAN	0.67	2.20	0.01	0.07	1.73	1.48	0.13	0.21
SD	0.66	1.74	0.05	0.20	2.18	2.20	0.36	0.57

Number of Samples = 7

B. CHLORINATED WATER

FEB	0.10	0.30	0.12	ND	0.46	ND	0.94	ND
MAY	0.86	2.20	ND	0.54	3.07	ND	ND	ND
AUG	1.30	0.43	ND	ND	ND	1.56	ND	1.50
DEC	ND	0.92	ND	ND	ND	1.21	ND	ND
MEAN	0.56	0.96	0.03	o.14	0.88	0.68	0.24	0.38
SD	0.62	0.87	0.06	0.27	1.47	0.79	0.47	0.75

Number of Samples = 4

ND = Not Detected

Table 25. TOTAL DDT AND ∝- BHC IN THE REUSED WATER OF APPP (ug/1)

MONTH	CHILLER		PRECHILLER		WASHER		SCALDER	
1978	DDT	∝-BHC	DDT	∝-BHC	DDT	∝-BHC	DDT	∝-BHC
MARCH	5.55	2.30	ND	1.50	ND	0.90	5.05	2.50
MAY	2.95	2.30	1.60	1.50	1.05	0.90	1.45	2.50
AUG	NA	1.32	NA	2.18	NA	2.60	NA	NA
NOV	0.87	1.47	1.39	0.91	2.25	0.97	3.15	0.77
MEAN	3.12	1.84	1.50	1.52	1.65	1.34	3.22	1.92
SD	2.35	0.46	0.15	0.45	0.85	0.73	1.80	0.82

ND= Not Detected
NA= Not Analysed

No. of samples = 4

TABLE 26. REMOVAL OF ∝-BHC AND TOTAL DDT FROM WASHING WATER BY FILTRATION

WATER SOURCE	NUMBER OF SAMPLES	HOURS AFTER STARTUP	MEAN CONCENTRATIONS IN ug/1 ∝-BHC	TOTAL DDT
FILTER INFLUENT	5	6	2.65	10.5
FILTER EFFLUENT	5	6	1.00	4.5
REMOVAL PERCENTAGE			62.2	57.1

EFFECT OF MULTIPLE WATER REUSE ON THE KEEPING QUALITY OF POULTRY

Three different operating conditions were selected to evaluate the effect of water renovation and reuse on the keeping quality of the processed poultry:

(i) Normal process (once through system)
(ii) TRT C (chlorine dose 20 mg/L, makeup rate:20 m^3/d)
(iii) TRT D (chlorine dose 20 mg/L, makeup rate:20 m^3/d)

In each experiment fourty randomly selected carcasses were collected after the final chilling process. The carcasses were left to drip on a disinfected rack and immediately packed in sterile plastic bags using sterilized gloves. This technique was followed to avoid any further contamination of the processed carcasses during the manual packing practiced at the plant.

The processed carcasses were transferred to the laboratory under aseptic conditions and were kept in a refrigerator at 4°C. Their positions on the racks were changed daily to ensure equal refrigeration during storage. This refrigeration temperature simulates prevailing conditions in the selling stands in Egypt.

The quality of the stored carcasses was tested bacteriologically and chemically. A sample of four carcasses was collected randomly. Peroxide value and acid value were performed on extracted chicken fat according to AOAC[20]. The TBA (2 Thiobarbituric acid) number was determined in the second and third experiments to detect the chemical changes during storage. Malonaldehyde concentration in the carcass was measured by the TBA method as recommended by Tarladgis et al[21]. The method is suitable for measuring the accumulation of the oxidative decomposition of highly unsaturated fatty acids, aldehydes and acids of low molecular weight.

These compounds are common products of bacterial activity during storage of muscles and fats of chicken carcasses.

The TBA number was determined both in the extracted fats and in the muscles, which was trimmed of the surrounding tissues and cut into transverse slices and then ground twice in a blender. This method although less sensitive than the peroxide value is nevertheless adequate for measuring the oxidative rancidity of tissue phospholipids and protein bound lipids which are responsible for the typical odor and deterioration products of meat tissue.

Total bacterial and coliform counts were performed daily on the sterile rinsing water collected from rinsing each

randomly selected four carcasses during the storage period.

The changes in the peroxide value of the extracted fat of cold stored chicken carcasses is reported in Table 27. Although the pattern of increase in fat peroxidation was similar in the three treatment conditions, the level was lower during treatments C and D as compared with the normal once through scheme. In additions, the peroxide value of chicken fat was relatively lower in TRT C in comparison with TRT D.

On the other hand, the results indicated that the rate of free fatty acid release was similar for treatments C and D, however higher than the normal scheme (Table 28). This may be attributed to the effect of the added chlorine which enhanced the breakdown of triglyceride into glycerol and free fatty acid.

The change in TBA number in the muscles and the extracted fats of cold stored chicken is shown in Table 29. The TBA numbers measured in the extracted fat were lower than their corresponding values in muscles. This can be explained by the inevitable losses during fat extraction due to the inability of the fat solvent used to extract protein bound lipids and phospholipids. This is in agreement with the finding of Tarladgis et al[21].

The total aerobic counts and coliform counts support the findings of the chemical parameter. Table 30 shows the average total bacterial count during storage of the carcasses.

Carcasses processed with the normal scheme started to show pronounced detrioration after the fifth day of storage while deterioration of those treated with TRT C or TRT D became evident on the seventh and sixth days of storage, respectively.

The results show that the overall bacterial load was low for TRT C, higher for TRT D and highest for the normal scheme. Coliform counts followed the same pattern as shown in Table 30. Bacteriological analyses were terminated by the eighth day as the carcasses were highly deteriorated and their quality was extremely unacceptable.

Table 27. MEAN AND STANDARD DEVIATION OF VALUES OF CHICKEN FAT PROCESSED BY VARIOUS TRTs OF PROCESS WATER DURING COLD STORAGE AT 4°C

DAYS	PEROXIDE VALUES m.mol/kg fat[a] CHLORINATION OF PROCESS WATER		
	NORMAL WATER USE	FILTRATION OF WASHER WATER	FILTRATION OF PRECHILLER WATER
		TRT C	TRT D
1	6.7 ± 0.6	2.5 ± 0.4	3.4 ± 0.5
2	11.0 ± 1.0		
3	49.7 ± 2.6	3.9 ± 1.1	4.7 ± 2.5
4	58.3 ± 2.9		
5	68.2 ± 4.8	10.1 ±	11.4 ± 2.9
7	113.3 ± 3.8	12.0 ± 3.2	13.0 ± 5.4
9	145.0 ± 6.1	15.2 ± 4.5	16.0 ± 6.8
10	207.5 ± 7.2	53.3 ± 6.1	68.7 ± 7.2

(a) Number of samples = 16

Table 28. MEAN AND STANDARD DEVIATION OF FREE FATTY ACID CONTENTS OF CHICKEN CARCASS PROCESSED WITH DIFFERENT WATER CONDITIONS DURING COLD STORAGE AT 4°C

DAYS	FREE FATTY ACIDS mg Na oH = 1gm fat[a] CHLORINATION OF PROCESS WATER		
	NORMAL WATER USE	FILTRATION OF WASER WATER	FILTRATION OF PRECHILLER WATER
		TRT C	TRT D
1	0.61 ± 0.10	2.00 ± 0.4	2.60 ± 1.2
2	0.64 ± 0.06		
3	1.28 ± 0.08	2.23 ± 1.1	3.20 ± 1.2
4	1.07 ± 0.17		
5	1.20 ± 0.15	2.40 ± 0.2	3.50 ± 0.4
7	1.60 ± 0.10	4.32 ± 1.3	5.20 ± 1.3
9	1.80 ± 0.30	7.30 ± 2.3	8.25 ± 2.5
10	2.93 ± 0.34	10.00 ± 2.8	10.00 ± 3.0

(a) Number of samples = 16

Table 29. MEAN AND STANDARD DEVIATION OF TBA NUMBER IN MUSCLE AND FAT OF CHICKEN CARCASSES PROCESSED WITH DIFFERENT WATER CONDITIONS DURING COLD STRONG AT 4°C

	TBA NUMBER IN MUSCLE (a)		TBA NUMBER IN FAT (a)	
DAYS	TRT C	TRT D	TRT C	TRT D
1	0.17 ± 0.1	0.3 ± 0.1	0.18 ± 0.08	0.19 ± 0.06
3	0.26 ± 0.1	0.5 ± 0.2	0.30 ± 0.06	0.39 ± 0.07
5	0.57 ± 0.2	0.8 ± 0.1	0.32 ± 0.05	0.74 ± 0.20
7	0.72 ± 0.2	0.9 ± 0.2	0.40 ± 0.05	0.91 ± 0.50
9	0.98 ± 0.6	1.2 ± 0.4	0.51 ± 0.06	1.10 ± 0.50
10	1.30 ± 0.7	1.5 ± 0.7	0.70 ± 0.09	1.60 ± 0.70

(a) Number of Samples = 16

It is postulated that efficient removal of the organic pollutants from the washing water (TRT C) made more chlorine available for disinfection rather than dissipation in chemical oxidation for organic constituents. In addition Fair et al[22], stated that at ordinary temperatures the hydrolysis of chlorine is essentially complete. At lower temperatures more hypochlorous acid is ionized to hypochlorite ion with considerable decrease in the killing efficiency.

Although the effective concentration of hypochlorous acid is reduced above pH 5.5, it is expected that the pH of 6.6 - 7.0 in all immersion tanks at APPP had a minor effect on the disinfection process.

Since the prechiller temperature is about 12°C lower than the washing water, it is expected that the available chlorine in the washer tank would give better disinfection than that acheived in the prechiller.

It is evident that renovation of recycled water and its application at reduced rate restored quality of the carcasses to the point where shelf-life equalled or exceeded that of carcasses processed in potable water under normal conditions.

Although chlorination may accelarate the rate of free fatty acid release during cold storage at 4°C, it also reduces the peroxidation rate of released fatty acids as shown in Table 29.

Table 30 BACTERIAL COUNTS OF CARCASSES PROCESSED BY VARIOUS WATER USE SYSTEMS[a]

DAYS	NORMAL WATER USE		TRT C		TRT D	
	LOGTC	LOGCC	LOGTC	LOGCC	LOGTC	LOGCC
0	2.72 b	2.30 b	2.60 b	2.00	2.72 b	2.18 b
1	3.20 c	2.43 c	2.96 c	2.36 c	3.00 c	2.40 c
2	3.68	3.11	3.20 d	2.70 d	3.28 d	2.86 d
3	4.79	4.45	3.85 e	2.96 e	3.96 e	3.00 e
4	5.57	5.34	4.08 f	3.11	4.30 f	3.72
5	7.41, x	6.82 x	5.83	4.95 f	6.99	4.97
6	7.64g,x	6.74 x	6.32	5.26	7.48g,x	6.32 ,x
7	7.95h,x	7.34 x	7.88h,x	6.83g,x	7.91h,x	6.89g,x
8	8.41j,x	7.78j,x	8.26j,x	6.72 ,x	8.30j,x	7.83j,x

a Logarithmic means of counts/ml of samples in four experiments (mean of sixteen samples)

b to j) The lower case letter follows values of the means which are not significantly different at the 5% level.

x) Detection of offensive odors.

LOGTC = Log Total count of carcass

LOGCC = Log Coliform count of carcass

It is worth noting that in the normal scheme in which no chlorine was used, fewer fatty acids were released, but peroxidation was considerably higher.

It is postulated that chlorination reduces the bacterial contamination and hence retards the bacterial peroxidation.

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